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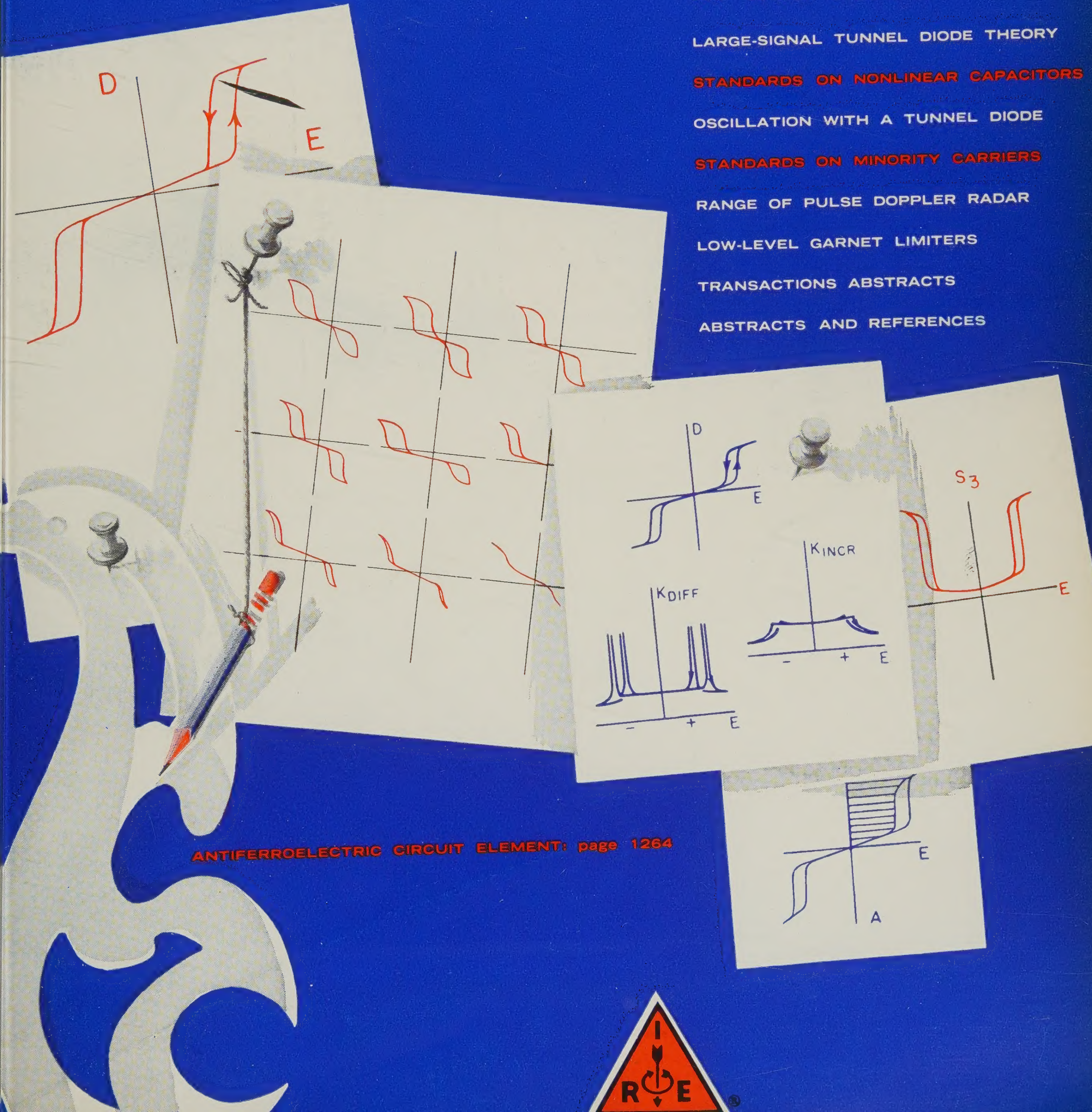
Proceedings of the IRE

in this issue

LARGE-SIGNAL TUNNEL DIODE THEORY
STANDARDS ON NONLINEAR CAPACITORS
OSCILLATION WITH A TUNNEL DIODE
STANDARDS ON MINORITY CARRIERS
RANGE OF PULSE DOPPLER RADAR
LOW-LEVEL GARNET LIMITERS
TRANSACTIONS ABSTRACTS
ABSTRACTS AND REFERENCES



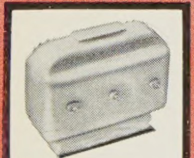
ANTIFERROELECTRIC CIRCUIT ELEMENT: page 1264

FIRST CHOICE FOR RELIABILITY

Designers of complex military and industrial equipment fully appreciate the need for extremely reliable components. For over a decade, UTC has been devoting constantly increasing manpower and dollars in the search for increased transformer and filter dependability. Investigation and analysis have been related to the life testing of large numbers of units to failure, plus thousands of wire-insulation-impregnant-potting and encapsulating systems. This program has resulted in proven materials, methods of structure and full quality controls which assure in UTC units an overall degree of reliability unequaled in our industry.

RELIABILITY UNDER ADVERSE ENVIRONMENT

As a leader in the production of extremely miniaturized components, UTC is a natural source for missile applications. Add to this the need for top reliability under adverse environmental conditions, and one can see why UTC units have been chosen for almost every missile from the Sidewinder to the Jupiter to the Atlas; our satellites, and project Mercury.



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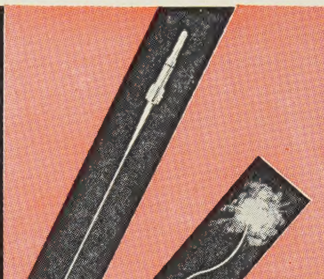
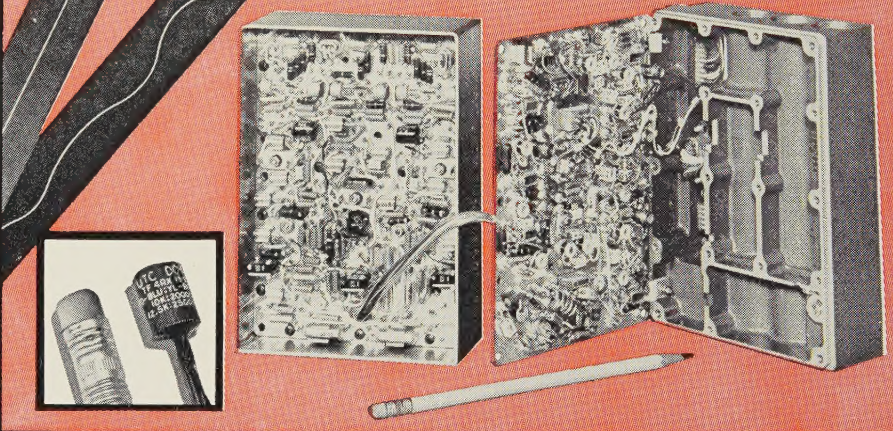


RELIABILITY TO DESTROY

A vital factor in second generation missiles is the sure ability to destroy the missile should something go wrong. UTC high reliability transformers were first choice for Ramo-Wooldridge in the design and production of their 4 pound AN/DRW-11 "command destruct" receiver which provides UHF FM signals to three command channels.



RELIABILITY TO NAVIGATE . . . CONTROL . . . COMMUNICATE

Manufacturers providing principal electronic gear for the B-58 chose UTC for optimum miniaturization with maximum reliability under adverse environment. In general aircraft use UTC high reliability units are found in virtually all applications such as Tacan, omnirange, intercommunication equipment, and fire control. The high inherent quality level of UTC airborne components is illustrated by over 19,000 units being shipped to one customer . . . then fully tested . . . with zero rejects.

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Proceedings of the IRE®

contents

Poles and Zeros 1261
Anthony B. Giordano, Director, 1961–1962 1262
Scanning the Issue 1263

PAPERS

Antiferroelectric Ceramics with Field-Enforced Transistions: A New Nonlinear Circuit Element, *Bernard Jaffe* 1264
Large-Signal Circuit Theory for Negative-Resistance Diodes, in Particular Tunnel Diodes, *M. Schuller and W. W. Gärtner* 1268
IRE Standards on Solid-State Devices: Definitions of Terms for Nonlinear Capacitors, 1961 1279
Self-Oscillation in a Transmission Line with a Tunnel Diode, *J. Nagumo and M. Shimura* 1281
IRE Standards on Solid-State Devices: Measurement of Minority-Carrier Lifetime in Germanium and Silicon by the Method of Photoconductive Decay 1292
Detection Range Predictions for Pulse Doppler Radar, *S. A. Meltzer and S. Thaler* 1299
Low-Level Garnet Limiters, *F. R. Arams, M. Grace, and S. Okwit* 1308

CORRESPONDENCE

The Silicon Cryosar, *H. Izumi* 1313
Noise Figure and Stability of Negative Conductance Amplifiers, *Alan C. Macpherson* 1314
Tunnel-Diode One-Shot and Triggered Oscillator, *T. W. Flowerday and D. D. McKibbin* 1315
A Tunnel-Diode Slot Transmission Amplifier, *Melvin E. Pedinoff* 1315
Neural Analogs, *L. D. Harmon and A. E. Brain* 1316
On Self-Organizing Systems, *P. D. Coleman* 1317
Stable Low-Noise Tunnel-Diode Frequency Converter, *F. Sterzer and A. Presser* 1318
Thin-Film Cryotrons, *V. L. Newhouse and H. H. Edwards* 1318
Are Electronics Engineers Educated?, *R. W. Johnson* 1319
A Note on Sugai's Class of Solutions to Riccati's Equation, *David C. Stickler* 1320
A New RMS Describing Function for Single-Valued Nonlinearities, *J. E. Gibson and K. S. Prasanna-Kumar* 1321
A Proposed Test of the Constancy of the Velocity of Light, *Pascal M. Rapier* 1322
Notes on the Structure of Logic Nets, *Robert M. Stewart* 1322
Suppression of Emission from Portions of Barium-Activated Tungsten Dispenser Cathodes and Adjoining Electrodes, *R. Levi and E. S. Rittner* 1323
Transmission Line Model, *J. D. Wallace* 1324
Antenna Siting Tests at 3480 and 9640 Mc on a 173-Mile Tropospheric Scatter Path, *N. D. La Frenais and W. J. Lucas* 1325
On the Linear Circuit Aspects of Cryotrons, *P. M. Chirlian and V. A. Marsocci* 1326
A Method for Determining the Base Voltage and Contact Resistance of a Conductivity-Modulated Diode, *J. M. Swartz and H. C. Gorton* 1326
Receivers with Zero Intermediate Frequency, *M. D. Rubin* 1327
A Magnetic Shield for Beam Frequency Standards, *F. S. Barnes* 1328
A Monopulse Instrumentation System, *Frederic P. Storke, Jr.* 1328
A Traveling-Wave Maser Using Chromium-Doped Rutile, *E. S. Sabisky and H. J. Gerritsen* 1329
Shaping of Distributed RC Networks, *B. L. H. Wilson and R. B. Wilson* 1330
Proposed Technique for Modulation of Coherent Light, *A. K. Kamal and S. D. Sims* 1331
A Generalization of "Mutual Information," *N. M. Blachman* 1331
A Broad-Band Termination for IF Coaxial Lines, *A. Susini and F. A. Ferger* 1332
Tracking and Display of Earth Satellites, *A. Van Gelder, Jr.* 1332
High-Level Microwave Detector Using Avalanche Injection, *H. M. Day and A. C. MacPherson* 1333
Coherent Generation of Microwave Power by Annihilation Radiation of a Prebunched Beam, *B. W. Hakki and H. J. Krumme* 1334
WWV and WWVH Standard Frequency and Time Transmissions, *National Bureau of Standards* 1335
Self-Educating Machines for Recognition and Classification of Patterns, *P. A. Clavier* 1335
On Parametric Amplification in Transistors, *J. Lindmayer, C. Wrigley, V. W. Vodicka, and R. Zuleeg* 1335
Multiple Burst Detection, *Francis Corr* 1337
An Analytical Expression for Describing the Write Process in Magnetic Recording, *T. C. Ku* 1337
A Potential Microwave Computer Element, *R. W. Couch, A. F. Rashid, and R. Spence* 1338
A Solution to the Shannon Switching Game, *A. Lehman* 1339

COVER

The array of curves shown on the cover portray the characteristics of a new dielectric ceramic circuit element capable of antiferroelectric-to-ferroelectric transitions, as described on page 1264.

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Proceedings of the IRE®

continued

The Wide Tuning Range of Backward Traveling-Wave Parametric Amplifiers, *H. Hsu and S. Wanuga* 1339
Correction to "Negative Resistance in Transistors Based on Transit-Time and Avalanche Effects," *R. A. Pucel and H. Statz* 1340
Correction to "Communications Satellites Using Arrays," *R. C. Hansen* 1340

REVIEWS

Books:

"Transistor Circuit Analysis," by M. V. Joyce and K. K. Clarke, *Reviewed by J. T. Lynch and J. J. Karew* 1343
"IRE Dictionary of Electronic Terms and Symbols (Compiled from IRE Standards)," *Reviewed by R. F. Shea* 1343
"Printed Circuits—Their Design and Application," by J. M. C. Dukes, *Reviewed by Thomas A. Prugh* 1343
"Line Waves and Antennas," by R. G. Brown, R. A. Sharpe, and W. L. Hughes, *Reviewed by Carl E. Smith* 1344
"Time-Harmonic Electromagnetic Fields," by Roger F. Harrington, *Reviewed by Charles H. Papas* 1344
"Theory of Microwave Valves," by S. D. Gvozdover, *Reviewed by C. W. Barnes* 1344
"Lectures on Communication System Theory," Elie J. Baghdady, Ed., *Reviewed by M. R. Aaron* 1345
"Electronic Drafting Handbook," by Nicholas M. Raskhodoff, *Reviewed by R. T. Haviland* 1345
"Electronics," by P. M. Chirlian and A. H. Zemanian, *Reviewed by W. R. Hill* 1346
"Progress in Semiconductors, Vol. 5," A. F. Gibson, F. A. Kröger, and R. F. Burgess, Eds., *Reviewed by W. M. Bullis* 1346
"Essentials of Dielectromagnetic Engineering," by H. M. Schlicke, *Reviewed by Charles F. Pulvari* 1347
"Radio Waves in the Ionosphere," by K. G. Budden, *Reviewed by M. G. Morgan* 1347
"Scientific Russian," by James W. Perry, *Reviewed by S. D. Browne* 1347
"Electrical Noise," by W. R. Bennett, *Reviewed by H. A. Haus* 1348
Recent Books 1348
Scanning the TRANSACTIONS 1348

ABSTRACTS

Abstracts of IRE TRANSACTIONS 1349
Abstracts and References 1358

IRE NEWS AND NOTES

Current IRE Statistics 14A
Calendar of Coming Events and Authors' Deadlines 14A
Professional Group News 18A

Programs:

Western Electronics Show and Conference (WESCON) 20A
Joint Nuclear Instrumentation Symposium 28A
National Symposium on Space Electronics and Telemetry 28A
Ninth Annual Engineering Management Conference 30A
Industrial Electronics Symposium 32A

DEPARTMENTS

Contributors 1341
IRE People 54A
Industrial Engineering Notes 34A
Meetings with Exhibits 8A
Membership 140A
News—New Products 128A
Positions Open 102A
Positions Wanted by Armed Forces Veterans 108A
Professional Group Meetings 39A
Section Meetings 133A
Advertising Index 153A

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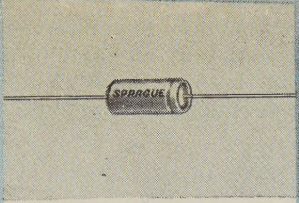

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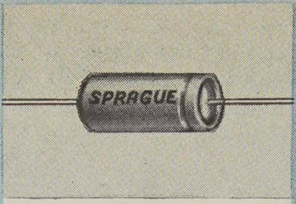

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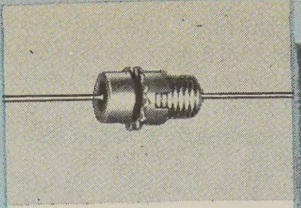

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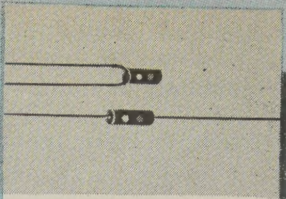

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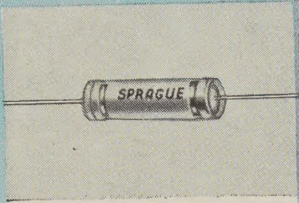

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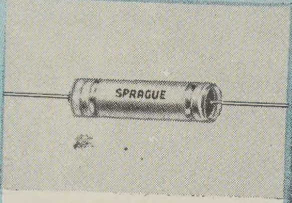

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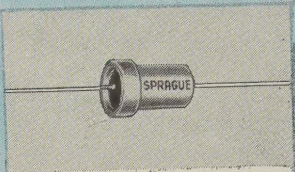

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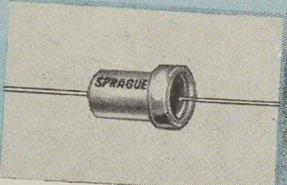

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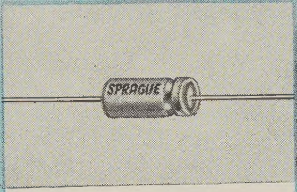

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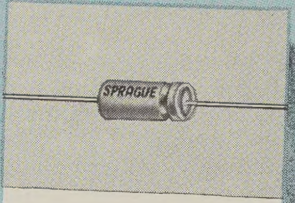

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The Airborne Instruments Laboratory Division of Cutler-Hammer, Inc., and the Central Radio Propagation Laboratory of the National Bureau of Standards have been working under NASA sponsorship on an ionospheric research program designed to orbit an ionosounder. The last two articles in this series described the history of the project and first-generation flight equipment. In this article, Warren Offutt concludes the discussion with a description of the satellite design.

Sounding the Ionosphere — From Topside

PART III

The design of the satellite ionosounder closely follows that of the rocket ionosounder described last month. The differences are the inclusion of solar cells, command receiving equipment, beacon tracking equipment, and two additional transceivers, providing a total of six sampling frequencies. The six sampling frequencies cover the range from approximately 3 to 10 Mc. Most of the usual problems found in the design of satellite equipment have been described many times in the literature, but the most serious problem has received only slight mention—that is, the reliability problem which, in designing for many months of operation, is of paramount importance.

Figure 1 is a functional reliability diagram of the Topside Ionosounder Satellite equipment. The best (and we believe good) estimates of hazard rate for each of the major functions are shown, expressed in failures per million hours (FPMH). The simple sum of the hazard rates for all functions is 214 FPMH. A simple sum calculation would be correct if any failure completely disabled the entire system. In a system in which certain failures will result in some loss of system capability rather than total disablement (as in the case of loss of only one transceiver), care must be used in interpreting the hazard rates. Also, it is usual for some system capabilities to be more important than others (in this case, the loss of certain sampling frequencies is deemed less harmful than the loss of others). We have found it helpful in our system design work to use the concept of system effectiveness. Effectiveness is that fraction of the total system performance available at a specified time. For example, Table 1 lists the predicted effectiveness for the system of Figure 1 at three specified times.

Table I

Predicted Effectiveness	*Time*
44.9 percent	at 6 months
30.1 percent	at 9 months
20 percent	at 12 months

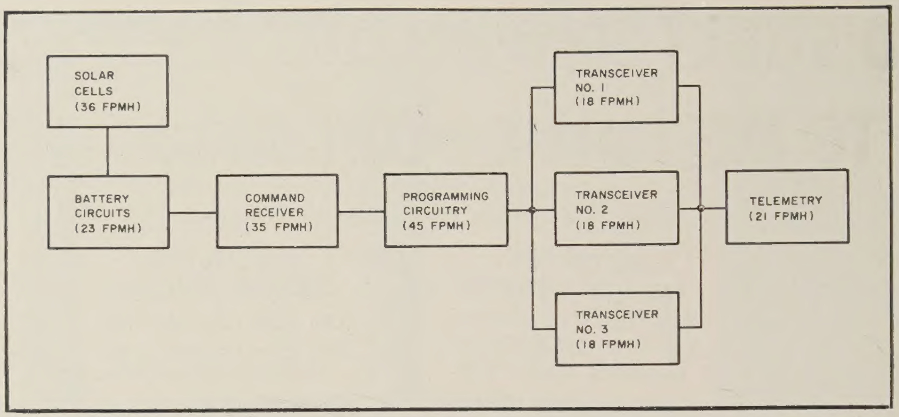
SOLAR CELLS (36 FPMH)
BATTERY CIRCUITS (23 FPMH)
COMMAND RECEIVER (35 FPMH)
PROGRAMMING CIRCUITRY (45 FPMH)
TRANSCEIVER NO. 1 (18 FPMH)
TRANSCEIVER NO. 2 (18 FPMH)
TRANSCEIVER NO. 3 (18 FPMH)
TELEMETRY (21 FPMH)

FIGURE 1. FUNCTIONAL RELIABILITY DIAGRAM

In other words, on the average, this system design should still provide 20 percent of its maximum information output after one year in orbit. Now, we would, of course, prefer to have a much higher figure, but the hard fact of this business is that even through careful simplification of design, additional redundancies, and the use of the very best component parts it has not been possible to increase the 20-percent figure to beyond 30 percent. Component parts available today are simply not good enough. In all honesty, however, note that these are *end point* effectiveness figures. The total information output, over the period from launch to end point, is the integral of the exponential effectiveness function and therefore is much more attractive to those needing an optimistic outlook on life in orbit. The integrated value should not be used where performance at end point is contemplated—such as a man-in-space program.

Another interesting problem we have encountered in the design of this equipment is the orbital thermal control problem. It is fairly easy to design a satellite package for reasonable temperatures, even if a large portion of the surface is covered with solar cells, when the orbit-sun-earth relation is constant. Over a several-month period, however, the polar orbit geometry runs the full gamut of noon-midnight (about 50 percent sunshine, 50 percent shadow) to "twilight" (100 percent sunshine). Active thermal control techniques using movable shutters offer a straightforward solution, albeit one that degrades reliability. On this project (and after operating an LGP-30 computer for many hours), we believe we have a thermal design that will hold internal temperatures within satisfactory limits for all expected orbital geometries. The secret is simply the very careful selection and control of the absorptivity/emissivity ratio over various parts of the exterior skin that are not covered by solar cells.

The flight schedule on this program calls for our first rocket probe tests about the time this will be in print. A full-fledged orbital test will be made in 1962. We hope to describe the results on this page at that time. Watch for it, won't you?

A complete bound set of our fifth series of articles is available on request. Write to Harold Hechtman at AIL for your set.

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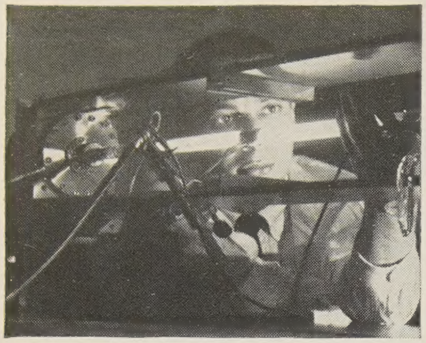
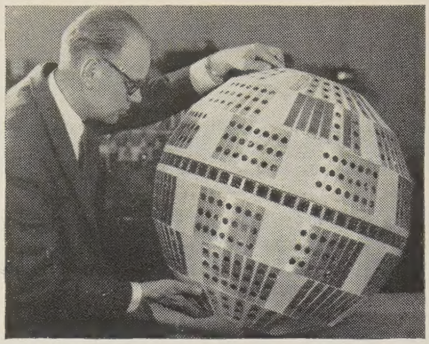
What was Bell Telephone Laboratories doing

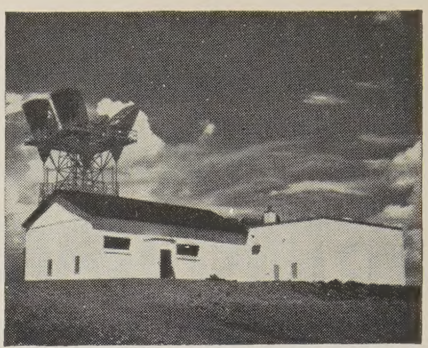
ON FRIDAY, JUNE 30, 1961?



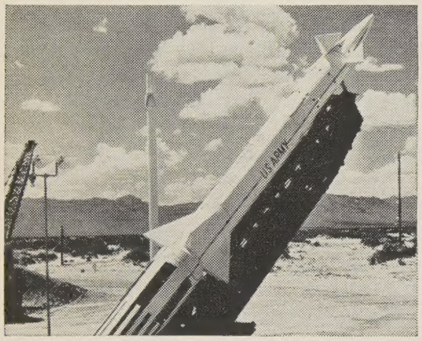
It was exploring the communications possibilities of the gaseous optical maser—a device which generates continuous coherent infrared radiation in a narrow beam.



It was preparing an experiment in world-wide communications using "active" satellites powered by the solar battery, a Bell Laboratories invention.

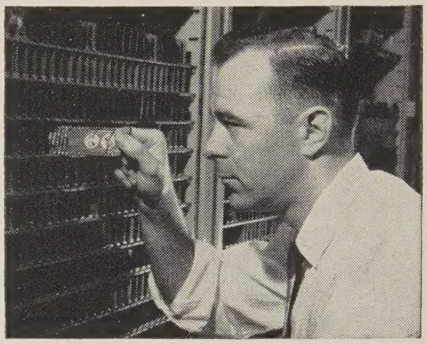


It was completing the development of a new "heavy route" Long Distance microwave system capable of handling over 11,000 two-way conversations at once.



It was developing an anti-missile defense system designed to detect, track, intercept and destroy an enemy ICBM—in a matter of minutes.

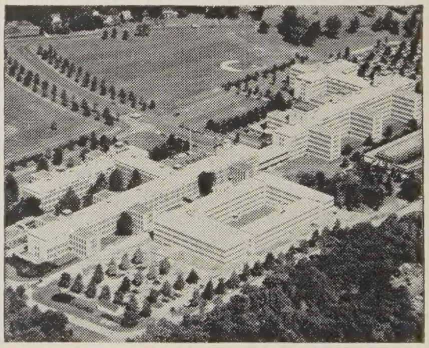
It was demonstrating the potentialities of the superconducting compound of niobium and tin for generating, with little power, magnetic fields of great strength.



It was experimenting with an electronic central office at Morris, Ill., which is capable of providing a wide range of new telephone services.

It was perfecting the card dialer which permits, through insertion of a punched card into a slot, automatic dialing of frequently used numbers.

It was developing improved repeaters or "amplifiers" to increase greatly the capacity and economy of undersea telephone cable systems.



It was continuing its endless search for new knowledge under the leadership of scientists and engineers with world-wide reputations in their chosen fields.

Bell Laboratories scientists and engineers work with every art and science that can benefit communications. Their inquiries range from the ocean floor to outer space, from atomic physics to the design of new telephone sets, from the tiny transistor to massive transcontinental radio systems. The goal is constant—ever-improving Bell System communications services.

BELL TELEPHONE LABORATORIES

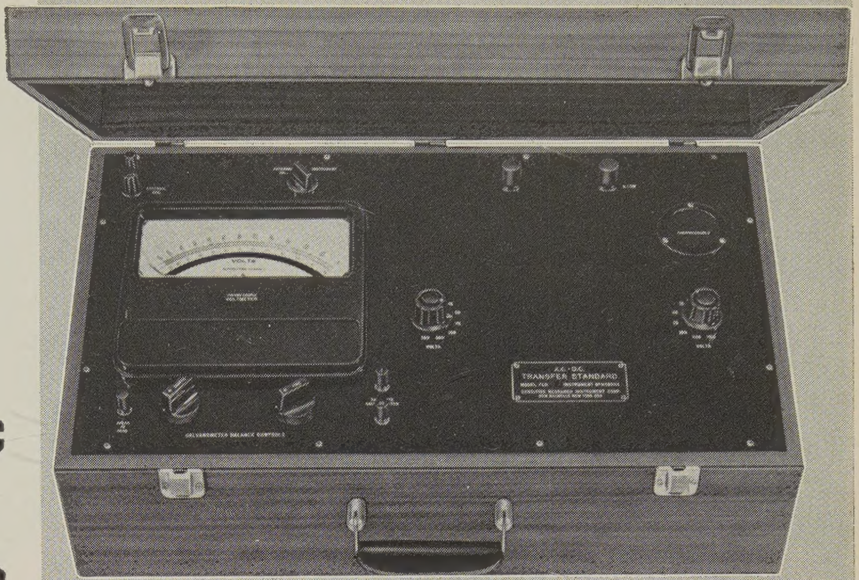
World center of communications research and development

SENSITIVE RESEARCH

A NEW AC VOLTAGE STANDARD

- **.01%* Accurate AC/DC Difference Measurements**
- **.013% Accurate Absolute AC Voltage Measurements**
- **Full Accuracy Over Entire Frequency Range from 20 cps—50,000 cps**
- **True RMS Response**

The Model FLH has been named in honor of Francis L. Hermach of the National Bureau of Standards in Washington, D. C., in recognition of his accomplishments in the field of AC/DC transfer measurements.



MODEL FLH

The Model FLH is a *NEW* thermocouple transfer standard designed to measure directly in percentage of reading, the influence of frequencies between 20 cps — 50,000 cps on the indication of voltmeters, calibrators, and other transfer standards over a range of 1.5 — 1125 v. It is supplied with an NBS Certificate* showing correction figures for those values of voltage where the AC/DC difference (or frequency influence) is, or exceeds, ±.01%. Typical performance characteristics are listed in the table on the left. These figures illustrate that it is seldom necessary to apply corrections to achieve substantially better performance than is basically guaranteed. Since the highest volt ranges have the greatest frequency influence, in practical usage the lower volt ranges can be considered to have either greater fundamental accuracy or a frequency span well beyond 50 kc.

The Model FLH when employed in conjunction with precision DC potentiometers and their accessories, is ideally suited for use in the certification of other AC voltage standards and the making of extraordinarily high accuracy absolute AC measurements. **An AC system accuracy of ±.013% can be obtained without difficulty** by combining the FLH with Sensitive Research "COMMANDER" Instruments such as the Dauphinee DC Potentiometer, Type 9144 (accuracy ±.001%), the NBS Volt Ratio Box, Type 9700A (accuracy ±.001%) and Saturated Standard Cells, Type 4305 and Constant Temperature Enclosure, Type 9152 (accuracy ±.001%). A "COMMANDER" Instrument Catalog is available upon request.

The basic accuracy of the Model FLH is derived from the flat frequency response of its multipliers. Long term resistor stability is of no importance. If the instrument is not physically impaired its frequency response will remain fixed indefinitely.

Replacement thermocouples are of the uncalibrated type.

ADDITIONAL SPECIFICATIONS

Accuracy using NBS correction figures: ±.01% of reading from 20 cps — 50 kc.*

Accuracy without using correction figures: ±.01% of reading to 30 kc from 1.5—450 v; ±.03% to 50 kc; ±.05% of reading to 30 kc from 450—1125 v; ±.075% to 50 kc.

Resolution:...... ±.005% minimum.

Price: ....$1685.00 (includes NBS Certificate and Type SR4 Galvanometer).

Terms: ....Net 30 days, f.o.b. NBS, Washington, D. C.

Write for additional information or contact your nearest SRIC sales representative.

FREQUENCY CORRECTIONS IN % OF READING MODEL FLH

VOLTS	20 Kc	30 Kc	50 Kc
1.5-4.5	0	0	+.01
above 4.5-11.25	0	0	0
above 11.25-22.5	0	0	0
above 22.5-45	0	0	—.012
above 45-112.5	0	0	—.015
above 112.5-225	0	0	0
above 225-450	0	0	—.026
above 450-1125	—.027	—.038	—.069

**It is the present policy of NBS to state their maximum measuring uncertainty as ±.02%. However, they are expected to reduce this possible error to ±.01% in the near future, and the instrument is guaranteed on this basis. It is also their present practice to limit testing to 30 kc on instruments of the Model FLH's accuracy unless the user is in a position to justify that certification to 50 kc or higher is imperative. Correspondence between NBS and the user is required in such an instance.*

S

Symbol of Quality

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y.

ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927

AIRPAX

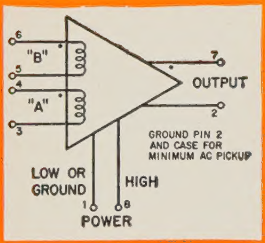
MAGNETIC AMPLIFIERS

60 CPS

PREAC
AMPLIFIER
AIRPAX
TYPE M-5551
FORT LAUDERDALE, FLA.

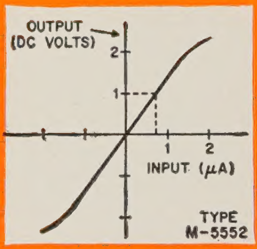
PREAC®

Fifty db power gain and full linear output with but milli-microwatt input power are inherent characteristics of the PREAC magnetic amplifier. Thermocouples, strain gauges, pressure transducers or high impedance sources may supply the input signal. Null drifts are as low as 1.0 micro-microwatt. Other applications include null and error detection, integration and summing, and use in sensitive micro-voltmeter and micro-ammeter circuits.



ELECTRICAL CONNECTIONS

TRANSFER CHARACTERISTICS



SPECIFICATIONS FOR 60 CPS PREAC AMPLIFIERS

	DC Microamperes Input for 1 DC Volt Output, 5K Load		Control Winding Resistance—Ohms		Bandwidth—CPS, with Tabulated Input Loop Resistance	
TYPE	Winding A	Winding B	Winding A	Winding B	Winding A	Winding B
M-5549	4.8	7.4	65	188	0.26 CPS/0.1K	0.6 CPS/0.1K
M-5550	1.2	7.4	980	188	0.32 CPS/2K	0.6 CPS/0.1K
M-5551	2.4	2.4	490	490	0.5 CPS/1K	0.5 CPS/1K
M-5552	0.7	7.4	2600	310	0.13 CPS/3K	0.6 CPS/0.1K

AIRPAX also produces a complete line of 400 CPS PREAC magnetic amplifiers.

AIRPAX ELECTRONICS INCORPORATED

6M33

SEMINOLE DIVISION FORT LAUDERDALE, FLA

Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups, which include exhibits.

Δ

August 22-25, 1961

Western Electronic Show and Convention (WESCON), Cow Palace and Fairmont Hotel, San Francisco, Calif.

Exhibits: Mr. Don Larson, WESCON, 701 Welch Road, Palo Alto, Calif.

September 6-8, 1961

National Symposium on Space Electronics & Telemetry, University of New Mexico Johnson Gym, Albuquerque, N.M.

Exhibits: Mr. C. H. Schmidt, 2901 Wisconsin N.E., Albuquerque, N.M.

October 2-4, 1961

Seventh National Communications Symposium, Hotel Utica & Utica Municipal Auditorium, Utica, N.Y.

Exhibits: Mr. R. E. Gaffney, General Electric Co., Light Military Electronics Dept., Utica, N.Y.

October 2-4, 1961

IRE Canadian Convention, Automotive Building, Exhibition Park, Toronto, Canada.

Exhibits: Business Manager, IRE Canadian Convention, 819 Yonge St., Toronto 7, Ontario, Canada.

October 9-11, 1961

National Electronics Conference, Hotel Sherman, Chicago, Ill.

Exhibits: Mr. Rudy Napolitan, National Electronics Conference, 228 N. LaSalle St., Chicago, Ill.

October 19-20, 1961

Sixth Annual Symposium on Electronics, Engineering and Education, Greensboro Coliseum, Greensboro, N.C.

Exhibits: Mr. H. G. Eidson, Jr., Dept. 8760, Charham Road Plant, Western Electric Co., Inc., Winston-Salem, N.C.

October 23-25, 1961

East Coast Conference on Aeronautical & Navigational Electronics, Lord Baltimore Hotel, Baltimore, Md.

Exhibits: Mr. Robert J. Henderson, Martin Company, Ground Support Equipment Dept., Baltimore, Md.

October 23-26, 1961

Eighth Annual Meeting, Professional Group on Nuclear Science (Aero-Space Nuclear Propulsion), Hotel Riviera, Las Vegas, Nevada

Exhibits: Mr. D. J. Knowles, Union Carbide Company, Oak Ridge National Lab., Oak Ridge, Tenn.

October 26-27, 1961

Electronic Techniques in Medicine & Biology Conference, University of Nebraska, Omaha, Neb.

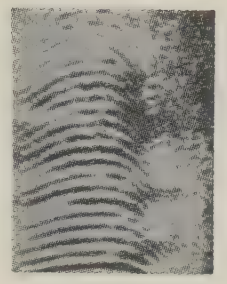
Exhibits: Mr. Harold G. Beenken, University of Nebraska, College of Medicine, 428 Dewey Avenue, Omaha, Neb.

(Continued on page 12A)

KAY AUDIO SPECTRUM ANALYZERS

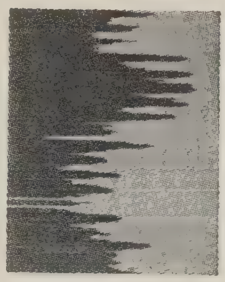
PERMANENT RECORDS

DISPLAY NO. 1



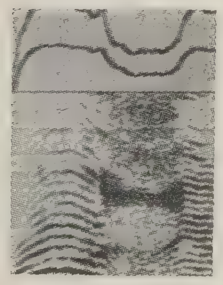
Frequency & Amplitude vs Time. —4" x 12" record on facsimile paper.

DISPLAY NO. 2

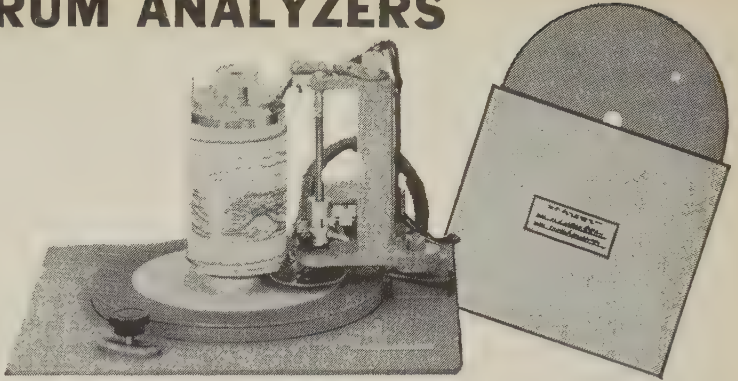


Intensity vs Frequency at Selected Time. Range: 35 db.

DISPLAY NO. 3



Average Amplitude vs Time. Logarithmic scale, 24 and 34 db ranges.



Kay Audio Analyzers employ a magnetic medium on which a selected (0.8 to 20 second) sample of a signal—transient and steady state—can be recorded and analyzed in a heterodyne type frequency analyzer. Both narrow and wide bandpass filters are available to emphasize either frequency resolution or time resolution. The permanent visual records are made on current sensitive facsimile-type paper.

KAY *Sona-Graph*® MODEL RECORDER

Catalog No. 662-A

- **85-12,000 cps**
- **Easily stored, permanent or re-usable magnetic disc recording**

The **Sona-Graph Model Recorder** is a new audio spectrograph for sound and vibration analysis. This instrument provides **four** permanent, storable records of any sample of audio energy in the 85—12,000 cps range . . . the three visual displays made by the **Sona-Graph 661-A** plus an aural record made on a 12" plastic-base magnetic disc which can be stored with the visual records.

SPECIFICATIONS

Frequency Range: 85 cps to 12 kc in two switched bands; 85 cps to 6 kc and 6 kc to 12 kc.

Frequency Response: ± 2 db over entire frequency range. Flat or 15 db high-frequency pre-emphasis in lower range.

Recording Medium: Plastic-base magnetic disc that can be removed and stored, or erased and re-used.

Analyzing Filter Bandwidths: 45 and 300 cps.

Recording Time: Any selected 2.4 second interval of any audio signal within frequency range.

Price: $2950.00 f.o.b. factory, $3245.00 f.a.s., New York.

NEW KAY *Missilyzer*®

5-15,000 cps

Catalog No. 675

- **Two separate channels for simultaneous recording of two signals.**
- **Remote control of recording and reproducing channel selectors.**

The **Missilyzer** is a wider range spectrum analyzer providing two identical channels for the simultaneous recording of two related signals. Built-in fast acting relays permit rapid automatic remote control.

SPECIFICATIONS

Frequency Range: Standard models, 5—15,000 cps, in bands listed below.

	Analyzing Filter Band		
Freq. Range	Narrow	Wide	Duration Recorded Sample
5-500 cps	2 cps	20 cps	24 seconds
15-1500 cps	6 cps	60 cps	8.0 seconds
50-5000 cps	20 cps	200 cps	2.4 seconds
150-15,000 cps	60 cps	600 cps	0.8 seconds

Record-Reproduce Amplifier Characteristics: Frequency response switchable to provide FLAT or (for transducer usage) either 44-db or 60 db falling characteristic.

Frequency Calibration: Calibration markers at 30 cps or 240 cps intervals may be recorded on analysis paper.

Input Impedances, Selectable: High, 1.8 Megohms for low level and microphone input. Low, for high level signals, such as from tape recorders.

Price: $2950.00 f.o.b. factory. $3245.00 f.a.s., New York.

KAY *Sona-Graph*® Catalog No. 661-A

An audio spectrograph in the 85—8000 cps range makes three permanent visual records.

SPECIFICATIONS

Frequency Range: 85-8000 cps.
Analyzing Filter Bandwiths: 45 and 300 cps.
Recording Time: Any selected 2.4 sec. interval of any audio signal within frequency range.
Record-Reproduce Amplifier Characteristics: Flat or 15 db high-frequency pre-emphasis for voice studies.
Microphone: Altec-Lansing 633A dynamic.
Input Impedance: 30 ohms.
Price: $2450.00 f.o.b. factory. $2695.00 f.a.s., New York.

KAY *Vibralyzer*® Catalog No. 651-A

An audio and sub-audio spectrograph in the 5—4400 cps range makes three permanent visual records.

SPECIFICATIONS

Frequency Range: 5-4400 cps in 3 bands.
Frequency Calibration: Markers at 30 cps or 240 cps intervals may be recorded on analysis paper.
Record-Reproduce Amplifier Characteristics: Frequency response switchable to provide FLAT (or for transducer usage) 44 or 60 db falling characteristic.
Pickup Devices: Vibration pickups: microphones or other properly matched devices may be used.
Input Impedance: High, 1.8 megohms.
Input Signal Sensitivity: Approx. 3 mv rms for full scale operation.
Price: $2495.00 f.o.b. factory. $2745.00 f.a.s., New York.

**Write For
Complete
Catalog
Information**

KAY ELECTRIC COMPANY

Dept. 1-8, Maple Avenue, Pine Brook, N.J., CApital 6-4000

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at WESCON
Booth #'s
3105 & 3107**

For Long Life and Power Economy

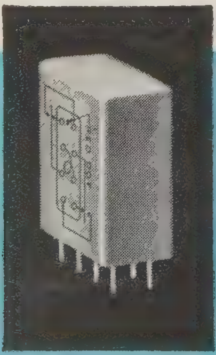
Specify the NEW

CLARE LATCHING SUBMINIATURE crystal can RELAY

The new CLARE Type LF, magnetic latching subminiature relay offers designers simplified circuitry in small space by providing latching effect without transistors. Magnetic latching results in power economy.

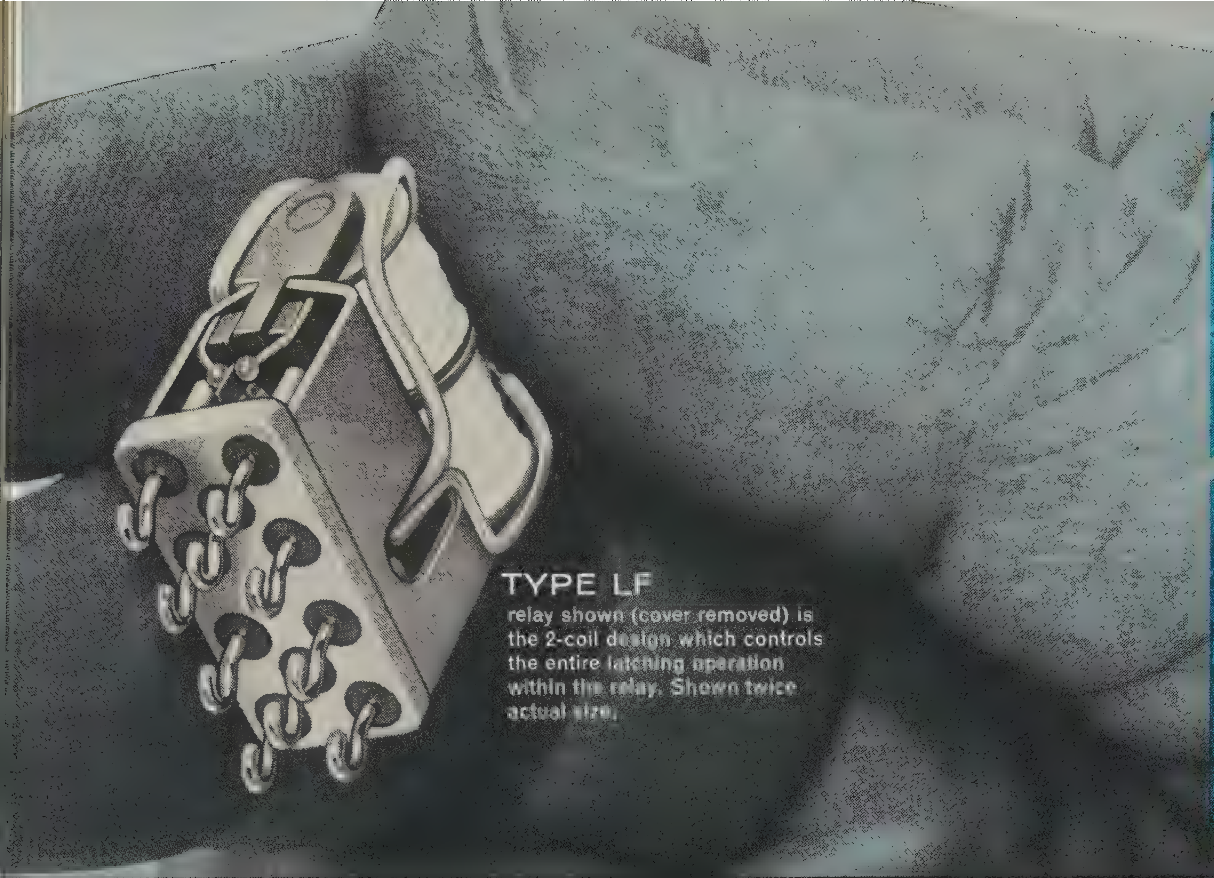
The Type LF is available with either 2-coil or 1-coil configuration. The 2-coil relay allows complete control of the latching operation within the relay and provides an extremely compact operating unit. The 1-coil relay is somewhat more sensitive; it is adaptable to existing circuits where outside control is provided. (See opposite page for specifications and circuit diagrams.) The Type LF provides the same wide range of mounting arrangements and terminals as the CLARE Type F relay.

FOR NON-LATCHING OPERATION



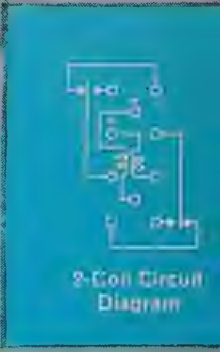
CLARE Type F Subminiature Crystal Can Relay

The CLARE Type F relay is extremely fast and more than moderately sensitive. It is built to withstand temperature extremes, heavy shock and extreme vibration. Contacts, rated at 3 amperes, are excellent for low-level circuit operations. Send for Design Manual 203.

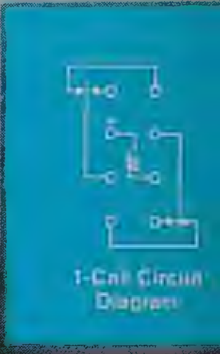


TYPE LF

relay shown (cover removed) is the 2-coil design which controls the entire latching operation within the relay. Shown twice actual size.



2-Coil Circuit Diagram



1-Coil Circuit Diagram

PHYSICAL FEATURES

Life Expectancy
- Wet Circuit:
  - 3.0 amperes, 28VDC resistive—100,000 operations
  - 2.0 amperes, 28VDC resistive—250,000 operations
  - 1.0 ampere, 28VDC resistive—1,000,000 operations
  - 1.0 ampere, 28VDC inductive (100 millihenry)—100,000 operations
  - 1.0 ampere, 115 VAC resistive—100,000 operations
- Dry Circuit:
  - 1,000,000 miss free operations when subject to conventional dry circuit requirements.

Temperature—+125° C to −65° C

Shock—100g's for 1/2 sine wave 11 ± 1 MS pulse

Linear Acceleration—100g's minimum

Vibration—.250″ DA or 30 g's, 5-2000 cps.

Humidity & Salt Spray—MIL-R-5757D

Enclosures: Tinned brass cover with fungus-resistant finish. Hermetically sealed and filled with dry nitrogen at atmospheric pressure.

Contact Arrangement—2PDT latching

Terminals—Plug-in (3/16″ straight), solder hook, 3″ straight

Wiring—Two coils (as shown on drawing above)
One coil (as shown on drawing above)

Weights—.54 oz. for plug-in
.62 oz. for 2 studs, 3″ leads

ELECTRICAL FEATURES

Operate Time—Two coil: When applying—for a minimum of 5 milliseconds—a voltage of at least two times the must operate voltage, the operate time including bounce will not exceed 5 milliseconds. One Coil: operate time will not exceed 8 milliseconds.

Sensitivity—Two coil, approximately 150 milliwatts
One coil, approximately 75 milliwatts

Dielectric Strength

Sea level: 1000 volts rms—all terminals to case
1000 volts rms—between contact sets
600 volts rms—between open contacts of a set
70,000 ft: 350 volts rms—all terminals to case

Insulation Resistance—1000 megohms minimum at +125° C between any two terminals and between all terminals and case.

Maximum Interelectrode Capacitance—

Closed contacts to case	3.7 picofarads
Open contacts to case	2.0 picofarads
Between contacts of a set	2.0 picofarads
Between adjacent contact sets	3.5 picofarads

Maximum Coil Dissipation

Two Coil: .50 watts at +125° C
.75 watts at +25° C
One Coil: 1.25 watts at +125° C
2.0 watts at +25° C

Standard Adjustment—Relay will operate and hold when the must operate voltage is applied

Contact Resistance:

Maximum: 50 milliohms at 6 volts, 100 milliamperes.
Typical: 25 milliohms at 6 volts, 100 milliamperes.

For coil and mounting data on CLARE Type LF relay send for CPC-12. Address: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 840 Caledonia Road, Toronto 19, Ontario. Cable Address: CLARELAY.

C. P. CLARE & CO. *Relays and related control components*

THE **SPECIALIST** IN

FREQUENCY COUNTERS

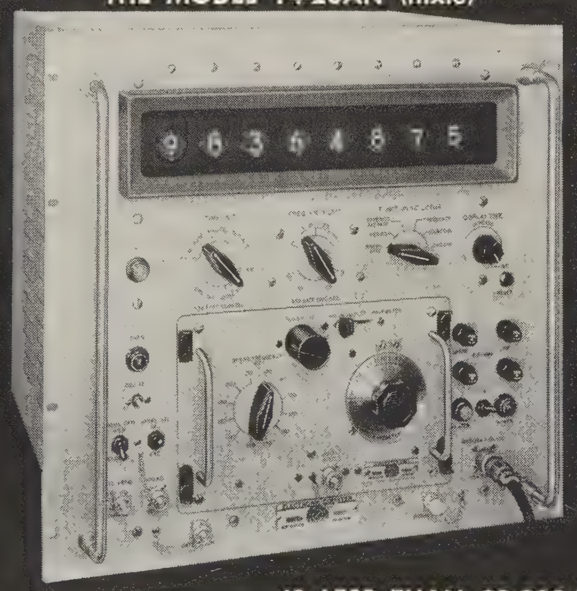
DEPENDABLE — proven on major missile programs, under most severe environments.

MAINTAINABLE — simplified, clean design; fewer tubes and diodes — more accessible — easier check-out.

DELIVERED from factory stock — no waiting.

PRICED right; low lease terms available.

THE MODEL 14-20AN (nixie)



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NORTHEASTERN ENGINEERING

An Affiliate of Atlantic Research Corp.

MANCHESTER • NEW HAMPSHIRE

Meetings with Exhibits

(Continued from page 8A)

November 6-8, 1961

Special Technical Conference on Non-Linear Magnetics, Statler Hilton Hotel, Los Angeles, Calif.

Exhibits: Mr. Philip Diamond, Perkin Electronics Corp., 345 Kansas St., El Segundo, Calif.

November 13-16, 1961

Conference on Magnetism & Magnetic Materials, Hotel Westward Ho, Phoenix, Ariz.

Exhibits: Mr. John L. Whitlock, 253 Waples Mill Road, Oakton, Va.

November 14-16, 1961

Mid-America Electronics Conference (MAECON), Hotel Muehlebach, Kansas City, Mo.

Exhibits: Mr. Felix A. Spies, Bendix Corporation, P.O. Box 1159, Kansas City 41, Mo.

November 14-16, 1961

Northeast Research and Engineering Meeting (NEREM), Boston Commonwealth Armory, Boston, Mass.

Exhibits: Miss Shirley Whitcher, IRE Boston Office, 313 Washington St., Newton, Mass.

November 30-December 1, 1961

PGVC Annual Meeting, Hotel Raddison, Minneapolis, Minn.

Exhibits: Mr. Harold T'Kach, Mobile Engineering, Inc., 620 North Sixth St., Minneapolis, Minn.

December 3-7, 1961

Eastern Joint Computer Conference, Sheraton-Park Hotel, Washington, D.C.

Exhibits: Dr. Jack Moshman, Capitol Radio Engineering Institute, 1200 Jefferson Davis Highway, Arlington 2, Va.

January 9-11, 1962

8th National Symposium on Reliability & Quality Control, Statler-Hilton Hotel, Washington, D.C.

Exhibits: Mr. M. P. Smith, Minneapolis-Honeywell Regulator Co., Aeronautical Div., 13350 U. S. Highway 19, Saint Petersburg, Fla.

February 7-9, 1962

3rd Winter Convention on Military Electronics, Ambassador Hotel, Los Angeles, Calif.

Exhibits: IRE Los Angeles Office, 1435 S. La Cienega Blvd., Los Angeles, Calif.

Δ

Note on Professional Group Meetings: Some of the Professional Groups conduct meetings at which there are exhibits. Working committeemen on these groups are asked to send advance data to this column for publicity information. You may address these notices to the Advertising Department and of course listings are free to IRE Professional Groups.

Hughes TWT capability offers you

New solutions for tube and systems problems

A continuing program of applied research by Hughes has resulted in the development of outstanding operating features such as those illustrated in the accompanying cutaway of a high-powered TWT.

When *you* have a requirement for an advanced microwave tube—CW or pulsed—consider TWT's, and Hughes. Perhaps the solution to your problem is already in development, or *production,* at Hughes.

For a more complete rundown on what Hughes can offer you, contact your nearest District Office today, or write for your copy of the Hughes short form catalogue.

NORTHEASTERN 4 Federal Street, Woburn, Mass. WEIls 3-4824

EASTERN 2000 "K" Street, N.W., Washington 6, D. C. FEderal 7-6760

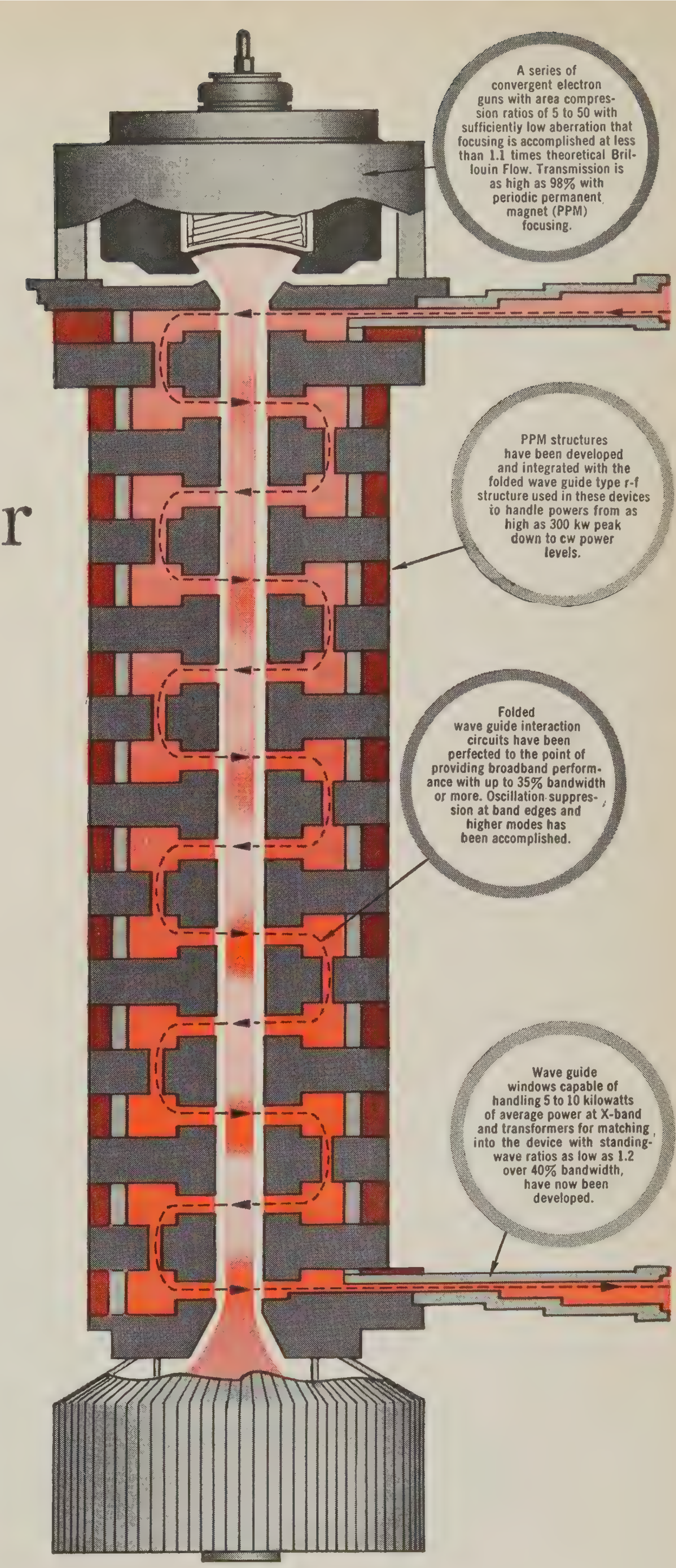
13 Lloyd Avenue, West Long Branch, N. J. CApital 2-1111

WESTERN 11105 South La Cienega Blvd., Los Angeles 45, Calif. SPring 6-1515

CREATING A NEW WORLD WITH ELECTRONICS

HUGHES

HUGHES AIRCRAFT COMPANY
MICROWAVE TUBE DIVISION



A series of convergent electron guns with area compression ratios of 5 to 50 with sufficiently low aberration that focusing is accomplished at less than 1.1 times theoretical Brillouin Flow. Transmission is as high as 98% with periodic permanent magnet (PPM) focusing.

PPM structures have been developed and integrated with the folded wave guide type r-f structure used in these devices to handle powers from as high as 300 kw peak down to cw power levels.

Folded wave guide interaction circuits have been perfected to the point of providing broadband performance with up to 35% bandwidth or more. Oscillation suppression at band edges and higher modes has been accomplished.

Wave guide windows capable of handling 5 to 10 kilowatts of average power at X-band and transformers for matching into the device with standing-wave ratios as low as 1.2 over 40% bandwidth, have now been developed.

IRE News and Radio Notes

Current IRE Statistics

(As of May 31, 1961)

Membership—89,567
Sections*—110
Subsections*—31
Professional Groups*—28
Professional Group Chapters—294
Student Branches†—210

* See this issue for a list.
† See June, 1961, issue for a list.

Calendar of Coming Events and Authors' Deadlines*

1961

WESCON, Cow Palace, San Francisco, Calif., Aug. 22–25.

3rd Internatl. Conf. on Analog Computation, Belgrade, Sept. 4–9.

Joint Nuclear Instrumentation Symp., North Carolina State College, Raleigh, Sept. 6–8.

Internatl. Conf. on Electrical Engrg. Education, Syracuse Univ., Adirondacks, N. Y., Sept. 6–13.

1961 Natl. Symp. on Space Electronics and Telemetry, Univ. of N. Mex., Albuquerque, N. Mex., Sept. 11–13.

IRE Conf. on Technical-Scientific Communications, Bellevue-Stratford Hotel, Philadelphia, Pa., Sept. 13–15.

9th Ann. Engrg. Management Conf., Roosevelt Hotel, New York, N. Y., Sept. 14–16.

National Exhibition of Radio and Television, Parc des Expositions, Paris, France, Sept. 14–25.

10th Ann. Industrial Electronics Symp., Bradford Hotel, Boston, Mass., Sept. 20–21.

CISPR, Univ. of Pennsylvania, Philadelphia, Oct. 1–6.

29th Ann. Meeting, Engrs. Council for Professional Dev., Sheraton Seelbach Hotel, Louisville, Ky., Oct. 2–3.

7th Natl. Communications Symp., Utica, N. Y., Oct. 2–4.

IRE Canadian Electronics Conf., Automotive Bldg., Exhibition Park, Toronto, Canada, Oct. 2–4.

11th Ann. Broadcast Symp., Willard Hotel, Washington, D. C., Oct. 6–7.

Natl. Electronics Conf., Internatl. Amphitheatre, Chicago, Ill., Oct. 9–11.

ARS Space Flight Rept. to the Nation, New York Coliseum, New York, N. Y., Oct. 9–15.

5th Natl. Symp. on Engrg. Writing and Speech, Kellogg Ctr. for Continuing Education, Michigan State Univ., East Lansing, Oct. 16–17.

Internatl. Conf. on Ionization of the Air, Franklin Inst., Philadelphia, Pa., Oct. 16–17.

6th Ann. North Carolina Section Symp., Greensboro Coliseum, Greensboro, Oct. 19–20.

* DL = Deadline for submitting abstracts.

(*Continued on page 15A*)

PGMTT National Symposium Issues Call for Papers

The 1962 PGMTT National Symposium will be held on May 22–24, at the Boulder Laboratories of the National Bureau of Standards in Boulder, Colo.

A call for papers concerned with research, development, and applications in all areas of the microwave field is hereby issued. The Technical Program Committee for the Symposium will be particularly interested in original, creative papers dealing with topics of relatively wide and current interest.

Prospective authors will submit both 50- 100-word abstracts and 500- 1000-word summaries accompanied by up to 6 figures, suitable for reproduction in a Symposium Digest, to be distributed to all registrants. This material should be sent to:

R. W. Beatty, Chairman
Technical Program Committee
1962 PGMTT National Symposium
National Bureau of Standards
Boulder, Colo.

Deadline for receipt of the above material is December 18, 1961. Notifications of acceptance or rejection will be sent out by January 15, 1962. Revisions of summaries of accepted papers for the Digest will be accepted until February 15, 1962.

Publication of a summary in the Digest will not prejudice later consideration of the complete paper for publication by the IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES. Submission of the complete paper for the Special Symposium Issue of these TRANSACTIONS is encouraged.

NAECON Publications Now Available

The NAECON office has announced that the following issues of the National Aerospace Electronics Conference publications are now available:

1954 *Digest*	$1.00
1955 *Digest*	$1.00
1957 *Proceedings*	$2.00
1958 *Proceedings*	$4.00
1960 *Proceedings*	$5.00
1961 *Proceedings*	$5.00

Checks should be made payable to the National Aerospace Electronics Conference, and orders sent to the following address: NAECON Office, 1414 E. Third St., Dayton 3, Ohio, Att.: Mrs. M. S. Roberts, Office Manager.

Call for Papers

1962 IRE INTERNATIONAL CONVENTION

March 26–29, 1962

Waldorf-Astoria Hotel and the New York Coliseum New York N. Y.

Prospective authors are requested to submit all of the following information by:

October 20, 1961

1. 100-word abstract *in triplicate*, title of paper, name and address
2. 500-word summary *in triplicate*, title of paper, name and address
3. Indicate the technical field in which your paper falls:

Aerospace & Navigation Electronics
Antennas & Propagation
Audio
Automatic Control
Bio-Medical Electronics
Broadcast & Television Receivers
Broadcasting
Circuit Theory
Communications Systems
Component Parts
Education
Electron Devices
Electronic Computers
Engineering Management
Engineering Writing & Speech
Human Factors in Electronics
Industrial Electronics
Information Theory
Instrumentation
Microwave Theory & Techniques
Military Electronics
Nuclear Science
Product Engineering & Production
Radio Frequency Interference
Reliability & Quality Control
Space Electronics & Telemetry
Ultrasonic Engineering
Vehicular Communications

Note: Only original papers, not published or presented prior to the 1962 IRE International Convention, will be considered. *Any necessary military or company clearance of papers must be granted prior to submission.*

Address all material to: Dr. Donald B. Sinclair, Chairman
1962 Technical Program Committee
The Institute of Radio Engineers, Inc.
1 East 79 Street, New York 21, N. Y.

PGVC ANNOUNCES ANNUAL CONFERENCE

The 12th National Conference of the IRE Professional Group on Vehicular Communications will be held at the Radisson Hotel in Minneapolis, Minn., on November 30–December 1, 1961. An outstanding group of papers on the theme, "The Unseen Future of Vehicular Communications," will be presented, in addition to many new and interesting exhibits. A full program of ladies' activities is scheduled. For further information, contact: H. V. T'Kach, 620 N. 6 St., Minneapolis 11, Minn.

1962 CONFERENCE ON SOLID-STATE CIRCUITS ISSUES CALL FOR PAPERS

The 1962 International Solid-State Circuits Conference will be held on February 14–16, 1962, on the campus of the University of Pennsylvania and the Sheraton Hotel, Philadelphia, Pa.

The Conference, sponsored jointly by the IRE, the AIEE, and the University of Pennsylvania, will feature papers dealing with circuit properties, circuit philosophy, and design techniques related to solid-state devices in general areas, such as:

Solid-state memory, storage, and logic
Solid-state microwave amplification, oscillation, and conversion
Solid-state devices performing an integrated circuit function
Unconventional power supplies
Cryogenic applications
Optoelectronic applications
Advanced circuitry, with emphasis on significant developments in the art

Papers representing original contributions in these and related fields are invited. Abstracts—highlighting the nature of the contribution, its significance in the art and theoretical and experimental results—300–500 words in length, which can be accompanied by key illustrations, should be submitted on single-side, black-on-white, double-spaced typewritten form suitable for immediate reproduction, on or before November 1, 1961, to the Program Committee Secretary: R. H. Baker, Room C-237, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass.

Abstracts should be accompanied by author's name, affiliation address, and telephone contact on the first page, and author's name and abbreviated paper title on each subsequent page.

Members of the 1962 Conference Committee include: Chairman, J. J. Suran, General Electric Company, Syracuse, N. Y.; Secretary, E. G. Nielson, General Electric Company, Syracuse, N. Y.; Program Chairman, R. B. Adler, MIT, Cambridge, Mass.; Public Relations, Lewis Winner, 152 W. 42 St., New York 36, N. Y.

PGMTT *DIGESTS* AVAILABLE IN LIMITED QUANTITY

Copies of the 1961 PGMTT National Symposium *Digest* are now available in a limited quantity at $3.00 each. These *Digests* were a PGMTT Symposium "first" and were described as excellent by those who attended. While they last, *Digests* may be obtained from Frank Reggia, Microwave Branch 250, DOFL, Washington 25, D. C. Remittance should be made payable to 1961 IRE-PGMTT National Sympsoium.

The *Digest* covers twenty contributed papers which constituted four sessions describing Millimeter Waves, Parametric Devices, Ferrites, and Plasmas. Six invited papers for the two panel sessions on High Power Microwave Techniques and Low Noise Microwave Amplifiers are summarized. A complete paper, "Elementary Considerations of Noise Performance," included in the *Digest*, formed the basis of discussion for the System and Receiver Noise Performance Clinic.

Present at the 1961 annual banquet of the IRE Professional Group on Microwave Theory and Techniques were (*left* to *right*): Delmer Ports, Chairman of the IRE Washington Section; Dr. Paul R. Conroy of the U. S. Information Agency; Gustave Shapiro, PGMTT Administrative Committee member and Editor of the PGMTT Newsletter; and Ted Saad, Editor of the *Microwave Journal* and member of the PGMTT Administrative Committee.

Dr. Conroy, alias Ivan Serov, successfully impersonated a Soviet official in his first appearance on the speaker's platform and impressed the audience with information on recent Russian advances in the field of microwave theory. When his identity was subsequently revealed, the surprised amusement of the audience attested to the effectiveness of his original speech which, incidentally, had been followed by an open question-and-answer period!

Calendar of Coming Events and Authors' Deadlines*

(*Continued from page 14A*)

East Coast Conf. on Aerospace & Navigational Electronics, Lord Baltimore Hotel, Baltimore, Md., Oct. 23–25.

URSI-IRE Fall Mtg., Univ. of Texas, Austin, Oct. 23–25.

PGNS 8th Ann. Mtg. of Symp. on Aerospace Nuclear Propulsion, Hotel Rivere, Las Vegas, Nev., Oct. 24–26.

Symp. on Instrumentation Facilities for Biomedical Res., Sheraton Fontenelle Hotel, Omaha, Neb., Oct. 26–27.

1961 Electron Devices Mtg., Sheraton-Park Hotel, Washington, D. C., Oct. 26–28.

Radio Fall Mtg., Hotel Syracuse, Syracuse, N. Y., Oct. 30–31.

6th Ann. Special Technical Conf. on Nonlinear Magnetics, Statler Hilton Hotel, Los Angeles, Calif., Nov. 6–8.

Conf. on Electrically-Exploded Wires, Kenmore Hotel, Boston, Mass., Nov. 13–14.

Symp. on Electronic Systems Reliability, IRE Kansas City Section, Nov. 14.

7th Ann. Conf. on Magnetism and Magnetic Materials, Hotel Westward Ho, Phoenix, Ariz., Nov. 13–16. (DL*: Aug. 18, F. E. Luborsky, GE Co., Res. Lab., P. O. Box 1088, Schenectady, N. Y.)

NEREM, Somerset Hotel & Commonwealth Armory, Boston, Mass., Nov. 14–16.

Electronic Systems Reliability Symp., Linda Hall Library Auditorium, Kansas City, Mo., Nov. 14 (DL*: Sept. 1, Dr. A. Goldsmith, Wilcox Electric, Kansas City, Mo.)

PGVC Conf., Hotel Radisson, Minneapolis, Minn., Nov. 30–Dec. 1.

Eastern Joint Computer Conf., Sheraton-Park Hotel, Washington, D. C., Dec. 12–14.

1962

8th Natl. Symp. on Reliability and Quality Control, Statler Hilton Hotel, Washington, D. C., Jan. 9–11.

AIEE 1962 Winter General Meeting, New York, N. Y., Jan 28–Feb. 2.

3rd Winter Conv. on Military Electronics, Ambassador Hotel, Los Angeles, Calif., Feb. 7–9.

Internatl. Solid State Circuits Conf., Sheraton Hotel & Univ. of Pennsylvania, Philadelphia, Feb. 14–16. (DL*: Nov. 1, R. B. Adler, M.I.T. Lincoln Lab., Rm. C-237, Lexington, Mass.)

8th Scintillation and Semiconductor Counter Symp., Shoreham Hotel, Washington, D. C., Mar. 1–3.

IRE International Convention, Coliseum & Waldorf Astoria Hotel, New York, N. Y., Mar. 26–29. (DL*: Oct. 20, D. B. Sinclair, 1962 Technical Program Committee, Institute of Radio Engineers, 1 East 79 St., New York 21, N. Y.)

SWIRECO, Rice Hotel, Houston Texas, April 11–13. (DL*: Oct. 1, M. Graham, Rice Univ. Computer Project, Houston.)

* DL = Deadline for submitting abstracts.

URSI Symposium on Electromagnetic Theory

A Symposium on Electromagnetic Theory and Antennas will be held at the Technical University of Denmark, Copenhagen, on June 25–30, 1962, both days inclusive. It is to be sponsored by the International Scientific Radio Union and the Danish Academy of Technical Sciences. This will be a continuation of three previous symposia, namely, the Symposium on Microwave Optics, held at McGill University, Montreal, Canada, in 1953; the Symposium on Electromagnetic Wave Theory, held at the University of Michigan, Ann Arbor, Mich., in 1955; and the Symposium on Electromagnetic Theory held at Toronto University, Toronto, Canada, in 1959. The Symposium will be open to any interested person from any country. The President of the Symposium is Professor J. Rybner, a former Vice President of the IRE. Members and corresponding members of the Technical Program Committee, under the chairmanship of J. R. Wait (U. S.), are G. Barzilai (Italy), P. Bechmann (Czechoslovakia), K. Bochenek (Poland), J. Brown (U.K.), H. Bremmer (Holland), G. Eckhart (Germany), V. A. Fock (U.S.S.R.), W. Franz (Germany), Z. Godzinski (Poland), R. C. Hansen (U.S.), M. Kline (U.S.), H. L. Knudsen (Denmark), J. W. Loeb (France), N. Marcuvitz (U.S.), P. Mattila (Finland), M. A. Miller (U.S.S.R.), K. Morita (Japan), A. A. Oliner (U.S.), J. A. Ortusi (France), C. L. Pekeris (Israel), O.E.H. Rydbeck (Sweden), K. M. Siegel (U.S.), S. Silver (U.S.), G. Sinclair (Canada), A. Tonning (Norway), A. D. Wheelon (U.S.), and F. J. Zucker (U.S.).

The Symposium will be devoted to subjects of current importance in electromagnetic theory and its applications. Original papers dealing with the following subjects will be encouraged: electromagnetic fields in anisotropic media (such as the ionosphere, plasmas and ferrites), asymptotic diffraction theory, scattering and propagation in random media, quasi-static electromagnetic problems, partial coherence, theory of broadband antennas, antenna pattern synthesis, and dynamic antennas.

Most of the technical sessions will be opened with an introductory or survey paper and will then be followed by a series of shorter papers with interspaced discussions.

Papers to be considered for presentation should be sent to Symposium on Electromagnetic Theory and Antennas, Oster Voldgade 10 G, Copenhagen K, Denmark, for attention of the Technical Program Committee. These should be in the form of a three-page summary containing not less than 800 and not more than 1200 words. They should be carefully written as they will form the basis of selection. The deadline for receipt of these summaries *from all authors* is December 1, 1961. In fact, it would be desirable that as many papers as possible reach Copenhagen at a considerably earlier date. Also, it is mandatory that papers be presented (in English or French) by the author or by one of the authors in the case of multiple authorship.

Summaries of all accepted papers will be duplicated and sent to all those who have preregistered for the Symposium. The final manuscripts will not be needed until the Symposium itself. An editorial board, under the chairmanship of E. C. Jordan, will select those papers which are to be published in full in the Symposium *Proceedings*. It is expected that the remainder will be published in the form of summaries.

Further information about the symposium is available from: J. R. Wait, National Bureau of Standards, Boulder, Colo., or H. L. Knudsen, Secretary, Symposium on Electromagnetic Theory and Antennas, Oster Voldgade 10 G, Copenhagen K, Denmark.

New York Chapter to Hold Conference on Reliability

The more basic reliability tools of the electronic engineer are now fairly well known and understood through an extensive literature that includes the *Proceedings* of the first New York Conference on Electronic Reliability. More difficult to find in the literature are the techniques needed to plan and control the operational effectiveness of large, multimode electronic systems, and to allocate reliability requirements to their elements in such a way that the entire complex represents an optimum compromise between the conflicting factors of cost, size and weight, performance, and functional longevity.

To promote a wider understanding of this reliability function the Metropolitan New York Chapter of the IRE Professional Group on Reliability and Quality Control has scheduled its Second New York Conference on Electronic Reliability for October 20, 1961, under the general theme "System Reliability Engineering." This Conference will be held at New York University's College of Engineering, University Heights, N. Y., and will be under the joint sponsorship of the New York, Long Island, and Northern New Jersey Sections of the IRE.

Morning, afternoon and evening sessions will be conducted by well-known reliability specialists, and will deal with the system aspects of reliability, maintainability, and effectiveness, with specific reference to mathematical models, value trade-offs, and reliability cost. Advance registrations, with a $5.00 check, payable to the New York Conference on Electronic Reliability, may be sent to M. A. Benanti, Molecular Electronics Co., New Rochelle, N. Y.

Call for Papers

1962 Southwestern IRE Conference (SWIRECO)

April 11–13, 1962

Houston, Tex.

Prospective authors are requested to submit the title of their paper and author's name by October 1, 1961, to:

Professor Martin Graham
Rice University
Computer Project
Houston 1, Tex.

This Conference is sponsored by the Houston Section of the IRE.

Call for Papers Issued by Conference on Electronic Components

The 12th annual Electronics Components Conference, sponsored by AIEE, EIA and IRE, and with participation by ASQC and the Society for Non-destructive Testing, will be held in Washington, D. C., on May 8–10, 1962. This meeting is devoted to new developments in components, component processing techniques, component evaluation and component materials. The following topics suggest the scope of interest:

Classical components—R, L, C, linear and nonlinear, lumped and distributed.
Combined function devices—Integrated thin film circuits, multiple semiconductor devices, miniature modules.
Solid state applications—Ferroelectric, ferromagnetic, thermoelectric, magneto optic, electroluminescent.
Magnetics—Square loop components, memory devices, magnetic films, magnetostrictive devices.
Electromechanical devices and concepts—Switching devices, filters, delay lines
Microwave components
Filters and Networks
Connecting devices and techniques
Processing, assembly and measuring techniques
Non-destructive testing
Component reliability
Electronic materials
Component-systems planning and integration.

Prospective authors are invited to submit a 500-word summary to: H. A. Stone, Chairman, Technical Program Committee, Bell Telephone Labs., Murray Hill, N. J. before the October 9, 1961, closing date. To expedite prompt handling, 15 copies are requested. Authors will be notified of acceptance about November 15.

Final papers will be due on January 15, 1962, and will be published in the *Proceedings* of the Conference.

FOR CW ILLUMINATORS AND NAVIGATION

LOW NOISE OSCILLATORS

1 WATT TO 50 WATTS

SCALE: 2/3 ACTUAL SIZE
VA-503B
1 W min.
13.5 kMc
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13.3 kMc
VA-508
1 W min.
8.8 kMc
VA-514
2 W min.
10.0 kMc
VA-511
50 W min.
10.0 kMc
VARIAN VA-504B
VARIAN VA-511
AVAILABLE NOW!

Varian Associates' family of low-noise oscillator klystrons assures superior performance in such applications as CW illuminators, fixed-frequency doppler navigation transmitters, and similar uses.

All tubes in this low-noise family are two-cavity klystron oscillators. All are fixed-frequency. All are electrostatically focused. They cover a wide power range (from 1 W to 50 W). Tubes in K_u-band include the air-cooled VA-503B and the liquid-cooled VA-504B. Tubes in X-band include the air-cooled VA-514 and VA-508 and the liquid-cooled VA-511. All are available now.

Characteristics of the VA-511 are typical of the oscillators in this group. The VA-511 produces 50W minimum power at 10 kMc, and operates at 10 kV, 60 milliamperes. FM noise is less than 1 cycle. Weight, less than 24 oz.; size: 6¼ in. x 2¼ in. x 1¾ in.

For additional technical information on this fine family of klystron oscillators, address Tube Division.

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VARIAN A. G. (SWITZERLAND)

Professional Group News

At its meeting on May 22, 1961, the IRE Executive Committee approved the following new Chapters: PG on **Communications Systems**—Northern New Jersey Chapter; Joint PG on **Component Parts and Electron Devices**—Omaha-Lincoln Chapter; and PG on **Nuclear Science**—Omaha-Lincoln Chapter.

Congress on Automation To Meet in Turin

An International Congress on Automation under the patronage of the Associazione Italiana Nazionale per L'Automazione (A.N.I.P.L.A.) and the auspices of the "ITALIA '61" Committee will be held in Turin on September 24–26, 1961, at the headquarters of the Polytechnic, as part of the program of events to celebrate the first one hundred years of Italian unity.

Dr. Ing. Piero Giustiniani, Cavaliere del Lavoro, Managing Director of the Montecatini Company, will be the Chairman of the Congress; Prof. Dr. Ing. Antonio Capetti, Dean of the Turin Polytechnic, will be the Deputy Chairman of the Congress; Dr. Prof. Ing. Algeri Marino, Chairman of the Italian Committee for Automation of the National Research Council, will be the Chairman of the Scientific Committee.

The Congress will deal with the following five subjects:

Theory of automatic control.

Techniques and measuring instruments in automation.

Processing and conveyance of information in automation.

Application of automation in continuous manufacturing processes.

Application of automation in repetitive manufacturing processes.

Each section will have a chairman and one approved rapporteur chosen from among the most prominent foreign and Italian experts of the respective section.

Corporations, associations, firms and individuals, Italian and foreign, interested in the scientific, technical and application problems of automation, are invited to attend this meeting.

Application to attend the Congress should be made immediately to the Secretary, International Congress on Automation, 1, Piazza Belgiojoso Milan, Italy.

PGEWS Announces September Conference

The IRE Conference on Technical-Scientific Communications will be held September 14–15, 1961, at the Bellevue-Stratford Hotel in Philadelphia, Pa. It is sponsored jointly by the Professional Group on Engineering Writing and Speech and the Philadelphia Section of the IRE.

Conceived to focus attention on a problem of prime importance facing technology today—the need to improve the quality of technical communications—the Conference will explore faster, more efficient methods of processing and disseminating technical information. More than 20 leaders in science, industry, the military, education, publications, and documentation will examine the salient aspects of this area. Speakers and panels will seek a better understanding of the communications process, with the goal of evolving new techniques for dealing with its problems.

The speakers will not only discuss solutions to communications problems but will also describe what is being done today by industry, government, and education to streamline technical communications. The opening session on Thursday will define the technical scientific communications crisis and its impact on research, industry, education and government. Two concurrent afternoon sessions will be devoted, respectively, to a better understanding of the communication process (the communicator-audience relationship) and to basic techniques for improving technical communication. The two concurrent sessions on Friday morning will examine information processing methods (automatic language translation, abstracting and literature search techniques) and automation methods for storing and retrieving technical information. The Conference will close Friday afternoon with an open forum panel discussion of practical solutions. In addition, there will be distinguished keynote speakers at the luncheons planned for Thursday and Friday.

For further information, contact E. R. Jennings or George Boros, Program Co-Chairmen, Conference on Technical-Scientific Communications, IRE Office, Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia 4, Pa. Advance registration may be made through the Registrations Chairman at the same address.

Listed below are the scheduled speakers:

Isaac L. Auerbach, *President, Auerbach Electronics Corp.*

Robert S. Casey, *Chief Chemist, Schaeffer Co.*, "Oral Communication of Technical Information"

Beverly Dudley, *Project Director, Laboratory for Electronics, Inc.*,

E. K. Gannett, *Managing Editor*, PROCEEDINGS OF THE IRE, "The Need for Intelligible 'Intelligence'"

Irwin Hersey, *Editor, Astronautics*

Paul W. Howerton (*Proxy*), *Deputy Assistant Director, Central Intelligence Agency*, "The Exchange of Technical Information"

Raymond A. Jensen, *Executive Secretary, National Federation of Sciences*, "A Study of U. S. Technical Information Services, and How They Can Be Improved"

Sidney Kaplan, *Information Project Director, Radio Corporation of America*, "Storage and Retrieval of Technical Documentation: New Techniques and Problems for Attention"

Reginald O. Kapp (*Proxy*), *Dean, Faculty of Engineering, University College, London* "The Difference Between Recording and Conveying Technical Information"

Dr. H. H. Katz, *President, American Institute of Engineering and Technology*, "Visualization and Illustration of Technical Material"

Allen Kent, *Associate Director, Center for Documentation and Communications Research, Western Reserve University*, "Problems of Literature Search"

Philip J. Klass, *Avionics Editor, Aviation Week*, "Technical Conventions: The Cancer of Technology—Causes and Cures"

Charles LaFond, *Electronics Editor, Missiles and Rockets*

Charles O. Probst, *General Manager, Cinefonics, Cook Technological Center*, "The Role of Photographic Support for Technical Communications"

Robert S. Scott, *Associate Director, Government Relations, AeroSpace Corp.*, "Communication: The Binding Power"

Robert H. Sencer, *Professor, Writer's Institute, Rensselaer Politechnic Institute*, "Progress in Technical Communications Concepts"

Dr. Ralph R. Shaw, *Dean, Library School, Rutgers University*, "Parameters for Machine Handling of Information"

James W. Skinner, *President, Philco Corp.*

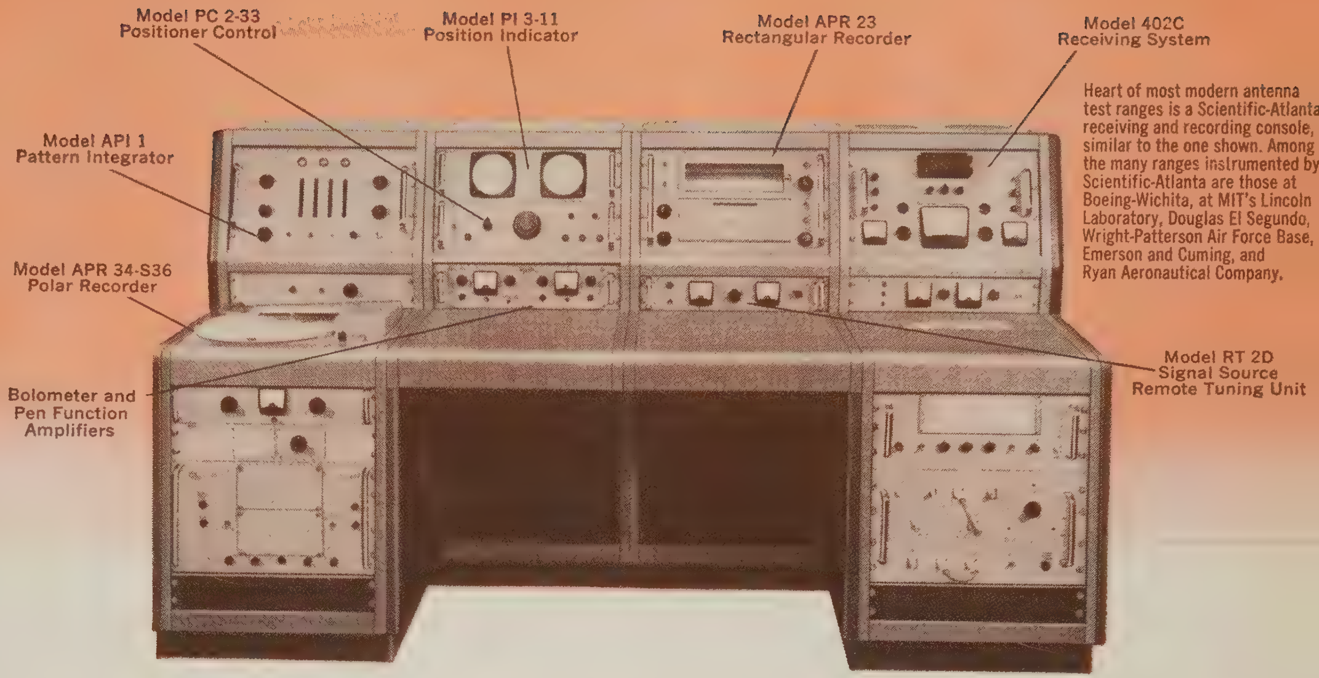
Dr. Bess Sondel, *Professorial Consultant in Communications, University of Chicago*

Raymond Stevens, *President, Arthur D. Little Co., Inc.*, "The High Cost of Poor Technical Communications in Research and Development"

Dr. John W. Tuckey, *Assistant Director of Research, Bell Telephone Laboratories, Inc.; Member of the President's Science Advisory Committee*, "Citation Indexes and Their Extension"

IRE Establishes New Subsection

At its meeting on June 20, 1961, the IRE Executive Committee approved the establishment of a new IRE Subsection, to be known as the Crescent Bay Subsection of the Los Angeles Section, and to encompass the following areas, cities, and postal zones in the State of California: Bel Air, Beverly Hills, Brentwood (Los Angeles 49), Culver City, (Los Angeles 56), Malibu, Mar Vista (Los Angeles 66), Ocean Park, Pacific Palisades, Palms (Los Angeles 34), Playa Del Rey, Preuss (Los Angeles 35), Rancho (Los Angeles 64), Santa Monica, Venice, Westchester (Los Angeles 45), West Los Angeles (Los Angeles 25), and Westwood (Los Angeles 24).



Heart of most modern antenna test ranges is a Scientific-Atlanta receiving and recording console, similar to the one shown. Among the many ranges instrumented by Scientific-Atlanta are those at Boeing-Wichita, at MIT's Lincoln Laboratory, Douglas El Segundo, Wright-Patterson Air Force Base, Emerson and Cuming, and Ryan Aeronautical Company.

ONE SOURCE
For Complete Antenna Instrumentation Systems

Recording, Receiving, Transmitting and Control Equipment, Antenna Positioners, Microwave Components, and Recorder Supplies

PATTERN RECORDERS—Two basic pattern recorders are available: the Series APR 20 Rectangular, and Series APR 30 Polar. They can be combined to form the popular APR 20/30 Polar-Rectangular Recorder. Pen responses include logarithmic, linear, and square root.

Features include servo control with tachometer feedback, a noise compression circuit, an electric pen lift, and a three-axis synchro input selector. The rectangular recorder has an automatic chart-cycle advance, illuminated chart, three chart scale expansions with forward-reverse, and chart position control. The polar recorder features a recording diameter of 7 and 13 inches, a turntable slip-clutch, pen standby and load switch, calibrated turntable, and chart center light.

WIDE RANGE RECEIVING SYSTEM—A double conversion superheterodyne receiver, the Scientific-Atlanta Series 402 covers the range from below 30 mc to more than 100 kmc.

Features include a sensitive AFC circuit which prevents the receiver from losing track during transmitter frequency drift. One coaxial cable eliminates costly lossy wave guides and rotary joints. Antennas can be located up to 75 feet away with negligible loss in sensitivity, or more than 200 feet away with low loss cables. Reception of cw signals from simple sources eliminates need for precise modulation.

Excellent employment opportunities exist for electronic, microwave, and mechanical engineers.

Modification P-4 adds 20 db to the normal 40 db dynamic range providing 1 db linearity over a full 60 db dynamic range. Modification Z adds a precision IF attenuator and VTVM appreciably reducing the number of components and instruments required for level, gain, and isolation measurements.

ANTENNA POSITIONERS—Scientific-Atlanta offers medium and heavy duty azimuth and multi-axis antenna positioners. Standard models range from the PMA-3 medium duty azimuth positioner designed for a maximum vertical load of 200 pounds with a maximum bending moment of 200 foot pounds to the large PAEA 29 H azimuth over elevation over azimuth for vertical loads of 15 tons and a bending moment of 30,000 foot pounds.

Features include use of Kaydon four-point contact bearings which minimize sliding friction, weather and dust proof design, and 1:1 and 36:1 speed synchros for each axis of rotation. Slip rings, rotary joints, and limit switches can be provided in any axis of any positioner.

MICROWAVE COMPONENTS—Scientific-Atlanta also offers a coaxial rotary joint for dc to 16 kmc at speeds up to 2000 rpm, a series of coax to waveguide adaptors, standard gain horns, crystal mixers, transmitting antennas, polarization positioners, model range towers and recorder supplies.

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1961 Western Electronic Show and Convention (WESCON)

COW PALACE, SAN FRANCISCO, CALIF., AUGUST 22–25, 1961

(See list of exhibitors on page 90A)

Tuesday Morning, August 22

Session 1—Broadband Antennas

Session Chairman and Organizer: *R. Justice, Granger Associates, Palo Alto, Calif.*

"Log-Periodic Resonant-V Arrays," *P. E. Mayes and R. L. Carrel, University of Illinois, Urbana.*

"Design Criteria for Log Periodic Antennas," *C. T. Elfving, Sylvania Electric Products, Inc., EDL, Mountain View, Calif.*

"Properties of a Pair of Wire Grids for Use in Lens-Type HF Antennas," *M. Andreasen and R. L. Tanner, Stanford Research Institute, Menlo Park, Calif.*

Panel Members: *D. Isbell, Boeing Co., Seattle, Wash.; R. DuHamel, Hughes Aircraft Co., Fullerton, Calif.; and T. Tice, Ohio State University, Columbus.*

Session 2—New Microwave Electron Devices

Session Chairman and Organizer: *J. T. Mendel, Hughes Aircraft Co., Culver City, Calif.*

"The Coaxial Magnetron, A Superior Microwave Power Source," *H. M. Olson and L. H. Von Ohlsen, Bell Telephone Labs., Laureldale, Pa.*

"Analysis of a Crossed-Field Waveguide Amplifier," *W. C. Brown and G. E. Dombrowski, Spencer Lab., Raytheon Co., Burlington, Mass.*

"Beam-Plasma Amplifiers," *M. A. Allen and G. S. Kino, Stanford University, Stanford, Calif.*

Panel Members: *J. F. Hull, Litton Industries, San Carlos, Calif.; J. Feinstein, S-F-D Labs., Union, N. J.; and R. Gould, California Institute of Technology, Pasadena.*

Session 3—High Speed Logic

Session Chairman and Organizer; *J. B. Angell, Stanford University, Stanford, Calif.*

"Relationships Between Device and System Design Factors in UHF Computers," *E. P. Stabler, General Electric Co., Syracuse, N. Y.*

"ASI—A High Speed Anti-Saturation Inverter Logic Circuit," *H. Ditkofsky and A. I. Pressman, RCA, Camden, N. J.*

"A Tunnel Diode—Tunnel Rectifier, 15 Nanosecond Memory," *M. M. Kaufman, RCA, Camden, N. J.*

Panel Members: *T. R. Finch, Motorola, Inc., Phoenix, Ariz.; R. M. Schults, Fairchild Semiconductor Corp., Mountain View, Calif.; F. K. Buelow, IBM Corp., Poughkeepsie, N. Y.; and J. S. Jamison, Philco Corp., Willow Grove, Pa.*

Session 4—Technological Advances in Military Electronic Equipment

Session Chairman and Organizer: *K. T. Larkin, Lockheed Missiles and Space Div., Sunnyvale, Calif.*

"Considerations for the Design of Micromodule Equipment," *B. I. Andrews, RCA, Camden, N. J.*

"Engineering Problems in Establishing a Thin Film Circuit Manufacturing Capability," *J. C. Gioia, General Electric Co., Utica, N. Y.*

"Development of Components for TIMM (Thermionic Integrated Micro Module) Systems," *W. A. Barrows and E. J. Broderick, General Electric Co., Owensboro, Ky.*

Panel Members: *S. B. Battdorf, Ford Motor Co., Newport Beach, Calif.; H. V. Noble, Sr., Air Force Systems Command, Wright-Patterson AFB, Ohio; and R. E. Bauer, Paktron Electronics, Alexandria, Va.*

Session 5—Electro-Optical Components

Session Chairman and Organizer: *W. D. Fuller, Lockheed Missiles and Space Div., Sunnyvale, Calif.*

"A Contactless Infinite Resolution Potentiometer," *P. H. Wendland, Electro Radiation, Inc., Santa Monica, Calif., and H. H. Houdyshell, Duncan Electronics, Inc., Costa Mesa, Calif.*

"The Photoreed—A New Versatile Frequency-Sensitive Control," *F. H. Inderwiesen, Midwest Research Institute, Kansas City, Mo.*

"A New Approach to Digital Displays Using Electroluminescence," *E. O. Stone, Sylvania Electric Products, Seneca Falls, N. Y.*

Panel Members: *R. Taylor, Varo, Inc., Garland, Tex.; M. Bailer, Aeronautical Systems Div., USAF, Wright-Patterson Air Force Base, Ohio; and R. Osche, U. S. Army Signal Research and Development Lab., Fort Monmouth, N. J.*

Tuesday Afternoon

Session 6—Current and Future Radio Astronomy and Techniques

Session Chairman: *H. Weaver, University of California, Berkeley.*

Session Organizer: *S. Silver, University of California, Berkeley.*

"Low Noise Receivers," *P. D. Strum, Applied Technology, Inc., Palo Alto, Calif.*

"Developments in Antenna Techniques for Radio Astronomy," *E-J. Blum, Observatory of Paris, Meudon, France.*

"Radio Astronomy in the Solar System," *E. A. Lilley, Harvard University, Cambridge, Mass.*

"Radio Astronomy Beyond the Planetary System," *G. Westerhout, Leiden, Netherlands.*

Session 7—Solid State Devices

Session Chairman and Organizer: *J. F. Gibbons, Stanford University, Stanford, Calif.*

"Superconductor Solenoids," *R. W. Boom and R. S. Livingston, Oak Ridge National Lab., Oak Ridge, Tenn.*

"Parametric Quartz Amplifier," *C. H. Becker, Westinghouse Electric Corp., Baltimore, Md.*

"Terrestrial Determination of Solar Cell Short Circuit Current Under Outer Space Solar Illumination," *H. K. Gummel and F. M. Smits, Bell Telephone Labs., Murray Hill, N. J., and A. R. Froiland, Smithsonian Observatory, Table Mountain, Calif.*

Panel Members: *J. M. Denny, Space Technology Labs., Los Angeles, Calif.; M. A. R. LeBlanc, Stanford University, Stanford University, Stanford, Calif.; and W. C. Dunlap, Raytheon Co., Waltham, Mass.*

Session 8—Computer Applications

Session Chairman and Organizer: *J. R. Anderson, Stanford Research Institute, Menlo Park, Calif.*

"PLATO: An Automated Teaching Device," *D. Bitzer, P. G. Braunfeld, and W. Lichtenberger, University of Illinois, Urbana.*

"The User Looks at the Information Storage and Retrieval Field," *R. R. Segel, Daniel, Mann, Johnson & Mendenhall, Los Angeles, Calif.*

"An Advanced Digital Data System for Use in Nuclear Reactor Development," *W. V. Botts, Jr., Atomics International, Canoga Park, Calif.*

Panel Members: *S. N. Alexander, National Bureau of Standards, Washington, D. C.; W. Sangren, General Atomic, Division of General Dynamics Corp., San Diego, Calif.; and D. C. Engelbart, Stanford Research Institute, Menlo Park, Calif.*

Session 9—Signal Selection

Session Chairman and Organizer: *N. Abramson, Stanford University, Stanford, Calif.*

"The Application of Time/Frequency Correlations Functions to the Continuous Waveform Encoding of Message Symbols," *C. A. Stutt, General Electric Co., Schenectady, N. Y.*

"A Criterion for Signal Selection Based Upon Comparison of Experiments," *T. L. Gretenberg, Stanford University, Stanford, Calif.*

"Signal Having Good Correlation Functions," *R. Lerner, Lincoln Lab., M. I. T., Lexington, Mass.*

Panel Members: *A. V. Balakrishnan, Space Technology Labs., Los Angeles, Calif.; J. Kelly, Bell Telephone Labs., Murray Hill, N. J.; and D. Van Meter, Litton Industries, Waltham, Mass.*

Session 10—R & D Personnel Management Aids

Session Chairman and Organizer: *O. T. Simpson, Philco Corp., Palo Alto, Calif.*

"Effectiveness of Engineering Employee Tests," *K. V. Newton, Bendix Corp., Kansas City, Mo.*

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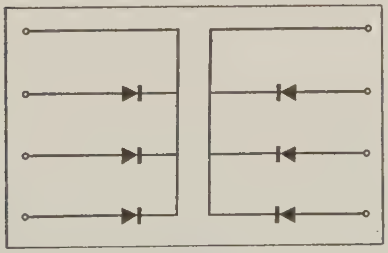
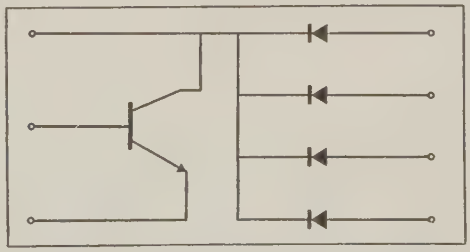


NC-1. Six Diode Assembly



NC-3. Diode-Transistor Logic Assembly

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"A Case Study of Performance Evaluation for a R/D Laboratory," *A. Addison and H. L. Yeagley, Jr., Pennsylvania State University, University Park.*

Industry Commentary: *J. A. Morton, Bell Telephone Labs., Murray Hill, N. J.; H. D. Ross, IBM Corp., New York, N. Y.; A. N. Curtiss, RCA West Coast Missile and Surface Radar Div., Van Nuys, Calif.; and D. W. Pugsley, Space Technology Lab., Los Angeles, Calif.*

Wednesday Morning, August 23

Session 11—Radio Astronomy Antennas

Session Chairman and Organizer: *C. L. Seeger, Stanford University, Stanford, Calif.*

"The Diffraction Theory of Large Aperture Spherical Reflector Antennas," *A. C. Schell, Air Force Cambridge Research Labs., Bedford, Mass.*

"Correlation Antennas with Non-Uniformly Spaced Elements for Incoherent Sources," *L. C. Davenport and C. J. Drane, Air Force Cambridge Research Labs., Bedford, Mass.*

"A High Resolution Radio Telescope," *J. L. Yen and D. A. MacRae, University of Toronto, Toronto, Canada.*

Panel Members: *W. N. Christiansen, University of Sydney, Sydney, N. S. W., Australia; E-J. Blum, Observatory of Paris, Meudon, France; and F. T. Haddock, University of Michigan, Ann Arbor.*

Session 12—Stereophonic FM Broadcasting

Session Chairman and Organizer: *R. A. Isberg, University of California, Berkeley.*

"Standards for Stereophonic Broadcasting," *H. Kassens, Federal Communications Commission, Washington, D. C.*

"Stereophonic FM Receivers and Adaptors," *D. R. von Recklinghausen, and H. H. Scott, Inc., Maynard, Mass.*

"Converting FM Broadcasting Stations for Stereophonic Transmission," *J. Gabbert, KPEN, San Frcncisco, Calif.*

Panel Members: *To be Announced.*

Session 13—High Density Tape Recording

Session Chairman and Organizer: *E. Tomash, Ampex Computer Products, Culver City, Calif.*

"Reproduction and Equalization of Pulses from a Magnetic Tape System," *G. J. Fan, IBM Corp., Yorktown Heights, N. Y.*

"High Density Digital Magnetic Tape Recording," *C. N. Batsel and W. L. Ross, RCA, Los Angeles, Calif.*

"Pulse Resolutions from Magnetic and Hall Reproduce Heads," *I. Stein, Ampex Corp., Redwood City, Calif.*

Panel Members: *D. Evans, Bendix Computer Div., Los Angeles, Calif.; M. Palevsky, Packard Bell Computer Corp., Los Angeles, Calif.; and F. Laub, National Cash Register Co., Hawthorne, Calif.*

Session 14—Detection and Signal Processing

Session Chairman and Organizer: *R. G. Davis, Lockheed Missiles and Space Div., Sunnyvale, Calif.*

"Crosscorrelation with Binary Signals," *G. R. Cooper, Purdue University, Lafayette, Ind.*

"Threshold Comparison of Phase-Lock, Frequency-Lock and Maximum Likelihood Types of FM Discriminators," *J. J. Spilker, Jr., Lockheed Missiles and Space Div., Palo Alto, Calif.*

"Classification and Evaluation of Coherent Synchronous Sampled Data Telemetry Systems," *A. J. Vitrebi, JPL, California Institute of Technology, Pasadena.*

Panel Members: *G. P. Dineen, Lincoln Labs., M. I. T., Lexington; E. J. Baghdady, M. I. T., Cambridge; and R. W. Sanders, Space Electronics Corp., Glendale, Calif.*

Session 15—Microwave Components and Techniques

Session Chairman and Organizer: *E. M. T. Jones, Stanford Research Institute, Menlo Park, Calif.*

"Microwave Variable Attenuators and Modulations Using *P-I-N* Diodes," *J. K. Hunton and A. G. Ryals, Hewlett-Packard Co., Palo Alto, Calif.*

"The Isomodulator," *H. Scharfman, Raytheon Co., Waltham, Mass.*

"A Practical Approach to the Design of Parametric Frequency Multipliers," *G. Luettgenau, J. Williams and H. Miyahira, Pacific Semiconductors, Inc., Lawndale, Calif.*

Panel Members: *K. Tomiyasu, General Electric Co., Schenectady, N. Y.; S. B. Cohn, Rantec Corp., Calabasas, Calif.; and B. A. Auld, Stanford University, Stanford, Calif.*

Wednesday Afternoon

Session 16—Methods of Reliability Improvement

Session Chairman and Organizer: *R. A. Davis, Palo Alto, Calif.*

"Redundancy and the Detection of First Failures," *D. C. James and A. H. Kent, The Martin Co., Denver, Colo.*

"Use of the Weibull Distribution Function in the Analysis of Multivariate Life Test Results," *A. A. Procassini and A. Romano, Motorola, Inc., Phoenix, Ariz.*

"KEWB—A Radiation Burst Test Facility," *W. M. Haussler, Atomics International, Canoga Park, Calif.*

Panel Members: *W. T. Sumerlin, Philco Corp., Philadelphia, Pa.; O. B. Moan, Lockheed Missiles and Space Div., Sunnyvale, Calif.; and C. S. Bartholomew, Boeing Airplane Co., Seattle, Wash.*

Session 17—Industrial Electronics

Session Chairman and Organizer: *R. De Liban, Barrett Electronics Corp., Menlo Park, Calif.*

"A Digital Control System for Refined Oil Blending," *C. A. Hill, Packard Bell Computer Corp., Los Angeles, Calif.*

"Radiography of Large Missiles with a Linear Electron Accelerator," *J. Haimson, Varian Associates, Palo Alto, Calif.*

"The Universal Digital Transducer," *A. Blaustein, Dejur Amsco Corp., Long Island City, N. Y.*

Panel Members: *R. A. Grimm, Hewlett-Packard Co., Palo Alto, Calif.; J. R. Walker, Gemco Electric Co., Detroit, Mich.; and V. H. Disney, Armour Research Foundation, Chicago, Ill.*

Session 18—Navigation and Air Traffic Control

Session Chairman and Organizer: *H. Blanchard, Stanford Research Institute, Menlo Park, Calif.*

"Self-Adaptive Flight Control Through Frequency Regulation," *R. G. Buscher, K. B. Haefner and M. F. Marx, General Electric Co., Schenectady, N. Y.*

"A Pictorial Navigation Situation Display," *E. S. Guttmann, Gilfillan Bros., Los Angeles, Calif.*

"Air Traffic Control Color Film," *M. G. Ettinghoff and P. D. Strosnider, General Precision, Inc., Glendale, Calif.*

Panel Members: *K. C. Black, Wayland, Mass.; W. T. Carnes, Jr., Aeronautical Radio, Inc., Washington, D. C., and S. Weissmann, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio.*

Session 19—Signal Processing

Session Chairman and Organizer: *L. Zadeh, University of California, Berkeley.*

"Properties of Narrowband Wave forms Generated by Clocked Pulses," *M. P. Ristenbatt, University of Michigan, Ann Arbor.*

"Communication in the Presence of Statistically Dependent Interference," *N. Blachman, Sylvania Electric Products, EDL, Mountain View, Calif.*

"Theory of Coherent Systems," *W. M. Brown and C. J. Palermo, University of Michigan, Ann Arbor.*

Panel Members: *P. Green and R. Price, Lincoln Lab., M. I. T., Lexington, and P. Swerling, Rand Corp., Santa Monica, Calif.*

Session 20—Components in Extreme Environments

Session Chairman and Organizer: *L. S. Shuey, Sprague Electric Co., Los Angeles, Calif.*

"Semiconductors in a Hyper-Nuclear Environment," *L. B. Gardner and A. B. Kaufman, Litton Systems, Inc., Woodland Hills, Calif.*

"Thermal Characteristics and Time-Temperature Studies of Miniature Electrical Connectors," *C. D. Stephenson, Amphenol-Borg Electronics Corp., Chicago, Ill.*

"Transient Radiation Effects in Capacitors and Dielectric Materials," *H. W. Wicklein and R. H. Dickhaut, Boeing Airplane Co., Seattle, Wash.*

Panel Members: *G. Carp, General Electric Co., Syracuse, N. Y.; J. Spergel, U. S. Army Signal Research and Development Lab., Fort Monmouth, N. J.; J. Easley, Sandia Base, Albuquerque, N. M.*

Wednesday Evening

Session 41—Arms Control

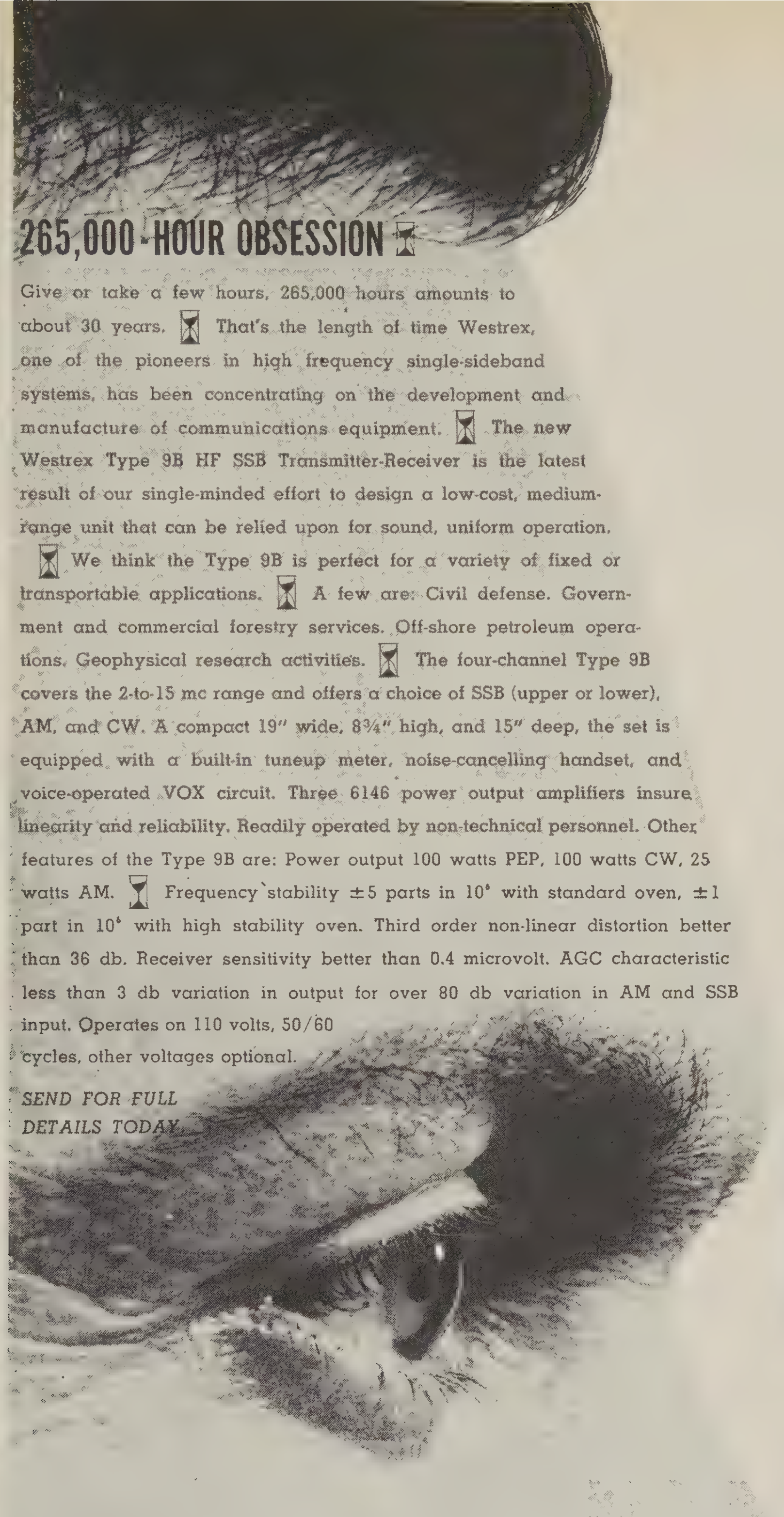
Session Chairman: *L. C. Van Atta, Office of the Director of Defense, Washington, D. C.*

Recognizing the wide-spread interest and concern with the problem, WESCON plans an evening session at which a group of specially-qualified individuals from government and the scientific community will discuss the background, current status, and future implications of the arms control effort, with particular emphasis on the implications for research and development.

Thursday Morning, August 24

Session 21—Point-to-Point Communications Via Satellite Relays

Session Chairman and Organizer: *G. J. D. O'Connell, General Telephone and Electronics Labs., Inc., Menlo Park, Calif.*



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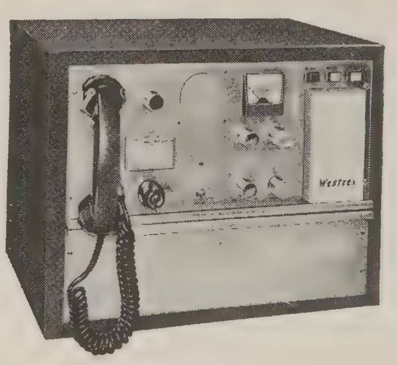

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"Twelve Advantages of Stationary Satellite Systems for Point-to-Point Communication," *S. G. Lutz, Hughes Research Labs., Malibu, Calif.*

"Techniques for Incoherent Scatter Communication," *D. P. Harris, Lockheed Missiles and Space Div., Palo Alto, Calif.*

"The Operational Analysis of a New York-London Communication Satellite Link by Machine Calculation," *W. Williams, Jr., and L. K. Arquette, Bendix Systems Div., Ann Arbor, Mich.*

Panel Members: *To be Announced.*

Session 22—Circuit Design for Extending Performance

Session Chairman and Organizer: *V. H. Grinich, Fairchild Semiconductor Co., Palo Alto, Calif.*

"An Analysis of the Modes of Operation of a Simple Transistor Oscillator," *J. F. Gibbons, Stanford University, Stanford, Calif.*

"Theory and Design of Wide Band Parametric Converters," *E. S. Kuh, University of California, Berkeley.*

"Stable Low-Noise Tunnel Diode Frequency Converters," *F. Sterzer and A. Presser, RCA, Princeton, N. J.*

Panel Members: *M. E. Hines, Microwave Associates, Inc., Burlington, Mass.; F. Brand, U. S. Army Signal Research and Development Lab., Fort Monmouth, N. J.; and G. L. Matthaei, Stanford Research Institute, Menlo Park, Calif.*

Session 23—Nanosecond Techniques

Session Chairman and Organizer: *N. Pappas, Iconix, Inc., Palo Alto, Calif.*

"Nanosecond Pulse Measurements," *C. N. Winningstad, Tektronix Co., Beaverton, Ore.*

"A Triggered Nanosecond Pulsed Light Source," *T. G. Innes and Q. A. Kerns, University of California Radiation Lab., Berkeley.*

"Analysis and Measurement of Phase Characteristics in Microwave Systems," *P. Lacy, Wiltron Co., Palo Alto, Calif.*

Panel Members: *W. M. Goodall, Bell Telephone Labs., Red Bank, N. J.; and H. Davis, Dept. of Defense, Washington, D. C.*

Session 24—System Design Considerations in Military Electronics

Session Chairman and Organizer: *J. P. Day, Granger Associates, Palo Alto, Calif.*

"The Role of Electronics in the Spectrum Concept of Military Electronics," *E. Deimel, General Electric Co., Utica, N. Y.*

"System Design Considerations for Efficient Use of Automatic Test Equipment," *J. Rescoe, Hughes Aircraft Co., Culver City, Calif.*

"On the Meaning of Quantified Maintainability," *N. J. Maroulis, General Electric Co., Utica, N. Y.*

Panel Members: *R. E. Honer, Electro Instruments, Inc., San Diego, Calif.; and F. G. Jamison, Oceanographic Engrg., San Diego, Calif.*

Session 25—Coherent Optical Emission

Session Chairman and Organizer: *J. R. Singer, University of California, Berkeley.*

"Fundamental Aspects of Optical Masers," *J. R. Singer, University of California, Berkeley.*

"Some Potentialities of Optical Masers," *B. M. Oliver, Hewlett-Packard Co., Palo Alto, Calif.*

"The Ruby Maser as a Light Amplifier," *P. P. Kisliuk and W. S. Boyle, Bell Telephone Labs., Murray Hill, N. J.*

"Alkali Vapor Optical Masers," *H. Cummins, Columbia University, New York, N. Y.*

"Optical Maser Studies at Lincoln Laboratory," *H. A. Bostick, Lincoln Lab., M. I. T., Lexington.*

"Repetitive Hair-Trigger Mode of Optical Maser Operation," *M. L. Stitch, E. J. Woodbury, and J. H. Morse, Hughes Aircraft Co., Culver City, Calif.*

Session 42—Future Engineers Symposium

Session Chairman: *A. B. Simpkins, Delcon Corp., Palo Alto, Calif.*

The special session will consist of a competition among the five top technical papers submitted by student exhibitors at the Future Engineers Show. The author of the paper judged best by a panel of judges will receive the Frederick Emmons Terman Award of $250.00.

Thursday Afternoon

Session 26—Spectrum Congestion in Vehicular Communications

Session Chairman and Organizer: *D. E. Teall, Lenkurt Electric Co., Inc., San Carlos,*

"Multi Transmitter/Receiver Installation Problems and Cures" *S. Meyer, Hammarlund Mfg. Co., Inc., New York, N.Y.*

"Allocation of Frequencies for the Mobile Radio Service—Should Changes be Made?" *G. Olive, RCA, Camden, N. J.*

"The Use of the 15 KC Tertiary Channels in the 150 Mc Business Radio Service," *M. Peckhart, Motorola, Inc., Chicago, Ill.*

Panel Members: *To be Announced.*

Session 27—Microwave Tubes and Parameter Measurements

Session Chairman and Organizer: *W. H. Yocom, Varian Associates, Palo Alto, Calif.*

"A Broad-Banding Theory of the Klystron Amplifier Output Circuit," *C. Romiguiere, Compagnie Française Thomson-Houston, Paris, France.*

"The Use of Quasi-Static Mode Approximations in the Design of Broadband, Slow-Wave Structure Impedance Matches," *W. Raub, Microwave Electronics Corp., Palo Alto, Calif.*

"A 50-Milliwatt BWO and 0.5 Watt TWT for CW Operation at 50–60 kMc," *D. O. Melroy, Bell Telephone Labs., Murray Hill, N. J.*

Panel Members: *A. Staprans, Varian Associates, Palo Alto, Calif.; M. E. Hines, Microwave Associates, Burlington, Mass.; and A. Karp, Stanford University, Stanford, Calif.*

Session 28—Nonlinear Control System Theory

Session Chairman and Organizer: *E. I. Jury, University of California, Berkeley.*

"On the Application of Lyapunov's Second Method to the Synthesis of Nonlinear Control Systems," *A. Stubberud, C. T. Leondes, and M. Margolis, University of California, Los Angeles.*

"Mathematical Analysis of Automatic Gain Control Circuits," *R. C. Davis, Claremont, Calif.*

"Dual Mode Filtering of Polynominal Signals in Noise," *L. G. Shaw, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.*

"Panel Members: *A. Bergen, University of California, Berkeley; A. Rosenbloom, Space Technology Lab., Los Angeles, Calif.; and F. Kurzweil, IBM Corp., San Jose, Calif.*

Session 29—Spectrum Utilization for Space Communications

Session Chairman and Organizer: *J. Jenkins, Lockheed Aircraft Corp., Sunnyvale, Calif.*

"Impact of Space Communication on the Spectrum," *J. Hacke, Jr., General Electric Co., Santa Barbara, Calif.*

"Interference Considerations for Communications Satellites," *N. Berger, J. Downing, F. Fulton, and D. Harris, Lockheed Missiles and Space Div., Palo Alto, Calif.*

"Channel Utilization by Intermittent Transmitters," *F. Fulton, Jr., Lockheed Missiles and Space Div., Palo Alto, Calif*

Panel Members: *W. La Berge, Philco Corp., Palo Alto, Calif.; S. G. Lutz, Hughes Aircraft Co., Culver City, Calif.; and A. M. Peterson, Stanford Research Institute, Menlo Park, Calif.*

Session 30—Quantum Devices

Session Chairman and Organizer: *A. E. Siegman, Stanford University, Stanford, Calif.*

"Design and Operation of an Experimental Colidar," *E. J. Woodbury, J. M. Morse, R. S. Congleton, and M. L. Stitch, Hughes Aircraft Co., Culver City, Calif.*

"A Solid State Spin Echo Memory System for a Microwave Digital Computer," *L. K. Wanlass and J. R. Singer, University of California, Berkeley.*

"The Ammonia Beam Maser as a Standard of Frequency," *J. A. Barnes, D. W. Allan, and A. E. Wainwright, National Bureau of Standards, Boulder, Colo.*

Panel Members: *R. C. Rempel, Varian Associates, Palo Alto, Calif.; G. Makhov, University of Michigan, Ann Arbor; and R. Daly, T. R. G., Inc., Syosset, L.I., N.Y.*

Friday Morning, August 25

Session 31—Propagation Studies for New Communication Techniques

Session Chairman and Organizer: *V. R. Eshleman, Stanford University, Stanford, Calif.*

"Laboratory Simulation of VLF Propagation and Underground Antenna Performance," *T. C. Larter, M. E. Louapre, and A. Stogryn, Space Electronics Corp., Glendale, Calif.*

"Synchronized - Oblique Ionosphere Sounding for H-F OWF Determination," *R. D. Baker, R. D. Egan, and L. D. Seader, Granger Associates, Palo Alto, Calif.*

"Free Electron Scatter as a Communication Mode," *A. M. Peterson, Stanford University, Stanford, Calif.*

Panel Members: *R. K. Moore, University of New Mexico, Albuquerque; D. A. Hedlund, Raytheon Co., Waltham, Mass.; and V. C. Pineo, Lincoln Lab., M.I.T., Lexington.*

Session 32—Solid State Devices II

Session Chairman and Organizer: *G. Moore, Fairchild Semiconductor Corp., Palo Alto, Calif.*

"*P-N* Junction Charge Storage Diodes," *J. L. Moll, Stanford University, Stanford,*

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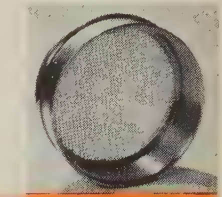

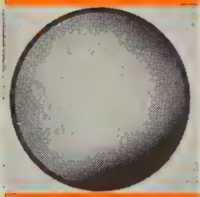

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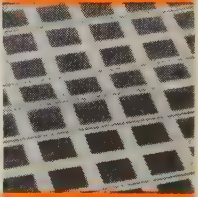
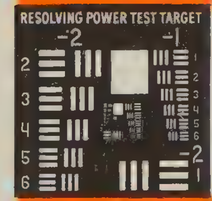
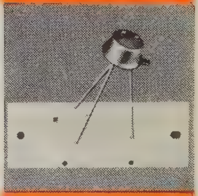
For Goodyear Aircraft and Bell Telephone Laboratories, BMC developed components for electrical domes with production accuracy of .015 inches in 17.48 feet.





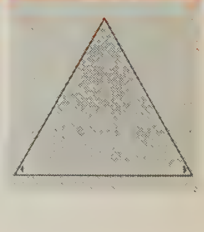
A resolution target for Air Reconnaissance Center, Wright Patterson Air Force Base—certified for all services.

Developed the mesa transistor masks for Bell Telephone Laboratories.



Pure nickel storage mesh, designed for Hughes Products—Tube Division, 21 inch radar storage tube.

Gold connector strips for transistors and gold resistors to measure micrometeorites in space.



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Calif.; S. Krakauer, Hewlett-Packard Co., Palo Alto, Calif.; and R. Shen, Harvard University, Cambridge, Mass.

"A New Semiconductor Tetrode, the Surface-Potential Controlled Transistor," *C. T. Sah, Fairchild Semiconductor Corp., Palo Alto, Calif.*

"*P-N-P* Double Diffused Germanium Switch," *J. Brixey and W. Jaeger, Texas Instruments, Inc., Dallas, Tex.*

Panel Members: *I. A. Lesk, Motorola Semiconductor Products Div., Phoenix, Ariz.; H. H. Loar, Bell Telephone Labs., Murray Hill, N. J.; and R. L. Pritchard, Texas Instruments, Inc., Dallas, Tex.*

Session 33—Modern Particle Accelerators

Session Chairman and Organizer: *H. G. Heard, Radiation at Stanford, Palo Alto, Calif.*

"The RF Systems for the Princeton-Pennsylvania Accelerator," *D. A. Barge, J. Kirchgessner, G. K. O'Neill, G. Rees, and J. Riedel, Princeton University, Princeton, N. J.*

"Beam Capture and Acceleration in the Brookhaven Alternating Gradient Synchrotron," *M. Plotkin, E. C. Raka, H. Hahn, and H. Halama, Brookhaven National Lab., Upton, N. Y.*

"The Zero Gradient High Intensity Proton Synchrotron," *A. V. Crewe, Argonne National Lab., Argonne, Ill.*

Panel Members: *W. A. S. Lamb, Lawrence Radiation Lab., Livermore, Calif.; D. A. Lind, University of Colorado, Boulder; and W. C. Parkinson, University of Michigan, Ann Arbor.*

Session 34—Coding for Reliability

Session Chairman and Organizer: *B. Elspas, Stanford Research Institute, Menlo Park, Calif.*

"On Time-Varying Coding Networks," *A. Marcovitz, Columbia University, New York, N. Y.*

"Sequential Decoding for Discrete Input Memoryless Channels," *B. Reiffen, Lincoln Lab., M.I.T., Lexington.*

"The Reliability of Coded and Uncoded Binary Messages as a Function of the Rate of Symbol Transmission," *R. D. Klein, Northeastern University, Boston, Mass.*

Panel Members: *D. Huffman and J. M. Wozencraft, Massachusetts Institute of Technology, Cambridge; and N. Zierler, California Institute of Technology, Pasadena.*

Session 35—New Techniques to Evaluate Product Design

Session Chairman and Organizer: *H. D. Kennedy, Granger Associates, Palo Alto, Calif.*

"Rank Correlation Testing Applied to Product Design," *I. R. Whiteman, C-E-I-R, Inc., Los Angeles, Calif.*

"A Survey of Applications of Radioactivity to Electronics," *A. J. Moses, Hazleton Nuclear Science Corp., Palo Alto, Calif.*

"Optimized Use of Industrial Design Technique," *D. J. McFarland, Latham-Tyler-Jensen, Inc., Long Beach, Calif.*

Panel Members: *A. Nowina-Sepinski, Consolidated Electrodynamics Corp., Pasadena, Calif.; N. H. Taylor, Itek Labs., Lexington, Mass.; and J. Fluke, John Fluke Mfg. Co., Inc., Seattle, Wash.*

Friday Afternoon

Session 36—New Developments in Communications Systems

Session Chairman and Organizer: *A. F. Culbertson, Lenkurt Electric Co., Inc., San Carlos, Calif.*

"The HC-270—A Four Phase Digital Data Transceiver," *J. E. Toffler and J. N. Buterbaugh, Hughes Communications Div., Los Angeles, Calif.*

"High Speed Serial Data Over Parallel, Low Speed HF Radio Links via Sepath," *C. S. Krakauer, Rixon Electronics, Inc., Silver Spring, Md.*

"Dependency of Crosstalk on Upper and Lower Cutoff Frequencies in PAM Time-Multiplexed Transmission Paths," *H. M. Straube, RCA, New York, N. Y.*

Panel Members: *R. G. Enticknap, Lincoln Lab., M.I.T., Lexington; C. G. Glenn, American Telephone and Telegraph Co., New York, N. Y.; H. Markey, IBM Corp., White Plains, N. Y.*

Session 37—Ultrasonic Aids to the Military and Industry

Session Chairman and Organizer: *G. G. Brown, Amsco Electronics Co., Palo Alto, Calif.*

"A Method for Non-Destructive Evaluation of Physical Properties in Rubber-Solid Compounds," *J. G. Martner, Stanford Research Institute, Menlo Park, Calif.*

"Evaluating Sonic Energy Cleaning," *T. Bulat, Bendix Corp., Davenport, Iowa.*

"The Effects of Bonding and Backing Materials on the Characteristics of Ultrasonic Delay Lines," *W. Konig, L. Lambert, and D. Schilling, Stanford Research Institute, Menlo Park, Calif.*

Panel Members: *O. Mattiat, Technical Dynamics, Santa Barbara, Calif.; F. Massa, Massa Division, Cohu Electronics, Inc., Hingham, Mass.; and F. T. Hueter, Minneapolis-Honeywell Regulator Co., Seattle, Wash.*

Session 38—Computer Theory

Session Chairman and Organizer: *R. I. Tanaka, Lockheed Missiles and Space Div., Sunnyvale, Calif.*

"A Decision Theoretic Approach to Machine Learning and Pattern Recognition," *D. Braverman, Stanford University, Stanford, Calif.*

"Diode and Transistor Logic in Synthesis of Symmetric Boolean Matrices," *H. K. Cooper, Pacific Semiconductors, Inc., Lawndale, Calif.*

"Logical Synthesis of Unit-Time Arithmetic Circuitry," *B. Singer, Case Institute of Technology, Cleveland, Ohio.*

Panel Members: *D. L. Epley, Stanford University, Stanford, Calif.; H. Garner, University of Michigan, Ann Arbor; and R. C. Minnick, Stanford Research Institute, Menlo Park, Calif.*

Session 39—The Use of Operator Characteristics in Electronic Systems

Session Chairman and Organizer: *R. S. Hirsch, IBM Advanced Systems Development Div., San Jose, Calif.*

"The Concept of 'Equalizing Ability' in Operator Selection and Training," *H. P. Birmingham and R. Chernikoff, U. S. Naval Research Lab., Washington, D.C.*

"Isolation of Human Performance Variables in an Operational Man-Computer System," *M. M. Okanes, System Development Corp., Santa Monica, Calif.*

"Decision-Making in Problems Utilizing Inductive and Deductive Inference," *H. C. Ratz and G. H. M. Thomas, University of Saskatchewan, Saskatoon, Canada.*

Panel Members: *G. Bekey, Space Technology Labs., Los Angeles, Calif.; H. R. Jex, Systems Technology, Inc., Inglewood, Calif.; and L. R. Zeitlin, Dunlap and Associates, Sunnyvale, Calif.*

Session 40—Microwave Solid State Devices

Session Chairman and Organizer: *P. S. Carter, Stanford Research Institute, Menlo Park, Calif.*

"An Electronically-Tunable Band-Reject Filter," *K. L. Kotzebue, Watkins-Johnson Co., Palo Alto, Calif.*

"A Non-Degenerate Traveling Wave Parametric Amplifier," *K. P. Grabowski, Hughes Aircraft Co., Fullerton, Calif.*

"Magnetically-Tunable Non-Reciprocal Band Pass Filter Using Ferrimagnetic Resonators," *C. Patel, Stanford University, Stanford, Calif.*

Panel Members: *G. Wade, Raytheon Co., Burlington, Mass.; R. DeGrasse, Microwave Electronics, Palo Alto, Calif.; and M. Weiss, Aerospace Corp., Los Angeles, Calif.*

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Joint Nuclear Instrumentation Symposium

North Carolina State College, Raleigh, September 6–8, 1961

The 1961 Joint Nuclear Instrumentation Symposium is scheduled for September 6–8 at North Carolina State College in Raleigh. The meeting is sponsored by the Nuclear Committees of the American Institute of Electrical Engineers, the Nuclear Industry Division of the Instrument Society of America, and the Professional Groups on Instrumentation and Nuclear Science of the Institute of Radio Engineers.

Pre-registration fees (before August 28) will be $17.50 for members of sponsoring societies (including educators); $3.00 for students (*Proceedings* $2.50 extra); $22.50 for nonmembers; and $3.50 for the banquet, which will be held at 7:30 P.M. on Thursday evening, September 7. Registration fees (after August 28) for members of sponsoring societies (including educators) will be $20.00; students, $3.00 (*Proceedings* $2.50 extra); nonmembers, $25.00; and the banquet, $5.00.

A bound set of the *Proceedings* will be furnished to the registrants.

Accommodations will be available at nominal rates in a new dormitory on campus.

Pre-registration may be made by writing to: North Carolina State College, College Extension Service, Raleigh, N. C., Att.: D. Stansel.

For further information write to: C. S. Lisser, Steering Committee Chairman, Oak Ridge National Lab., Oak Ridge, Tenn.

Wednesday Morning, September 6

Research Instrumentation and New Devices

"Reactor Power Monitor Utilizing Cerenkov Radiation," *J. L. Lovvorn, Oak Ridge National Lab.*

"High Current Regulated Supply for the Oak Ridge Cyclotron Combining Transistors and Magnetic Amplifiers," *W. H. White, Jr., B. C. Behr, and W. E. Lingar, Oak Ridge National Lab.*

"Application of Silicon Radiation Detectors," *L. Cathey, Dupont, Savannah River Lab.*

"A Sub-Millimicrosecond Current Amplifier Utilizing an Unusual Transistor Effect," *F. T. May, and R. A. Dandl, Oak Ridge National Lab.*

Wednesday Afternoon

Space Instrumentation

"Survey of Space Nuclear Instrumentation," *G. Ludwig, Goddard Space Center.*

"Gamma Ray Astronomy in Space in the 50KEV to 3MEV Region," *L. Peterson, University of Minnesota.*

"Instrumentation for Measurements in the Van Allen Belts," *W. Wheltley, University of Iowa.*

"University of Chicago Cosmic Ray Experiments above 0.5 MEV in Space," *J. Lamport, University of Chicago.*

Thursday Morning, September 7

Surveys of the State of the Art

"Our Changing Views of Reactor Instrumentation," *A. R. Pearson and C. G. Lennox, Atomic Energy of Canada, Ltd.*

"A Survey of Instrumentation in Particle Accelerators," *W. A. Higgenbotham, Brookhaven National Lab.*

(British Review Paper to be announced later).

"Capability of Safety Systems for Destroying Reactors," *E. P. Epler, Oak Ridge National Lab.*

Thursday Afternoon

Plasma Research Instrumentation

"A Survey of Plasma Instrumentation," *C. Wharton, University of California Radiation Lab.*

"The Use of Electrostatic Probes in Plasma Physics," *F. F. Chen, Princeton University.*

"Diagnostic Instrumentation in the UCRL Plasma Research Program," *W. F. Cumming, University of California Radiation Lab.*

"DCX Instrumentation," *H. Postma, Oak Ridge National Lab.*

"Soft X-Ray Plasma Diagnostics," *F. C. Jahoda, Los Alamos.*

Friday Morning, September 8

Process and Monitoring Instrumentation

"A Continuous Photometer for Low Concentration of Uranium in Aluminum Nitrate-Nitric Acid Solutions," *C. M. Slansky and E. E. Erickson, Phillips Petroleum, National Reactor Testing Site.*

"In-Line Gamma Monitor, Uranium Colorimeter," *J. W. Landry, Oak Ridge National Lab.*

"Savannah River Laboratory Criticality Incident Alarm System," *J. N. Wilson, Dupont, Savannah River Lab.*

"Failsafe AC High Low Limit Detector," *E. A. Bianchi and P. Lenk, Stromberg-Carlson.*

"Detailed Design of Airborne Uranium Dust Alarm with Less than Fifteen Minutes Response Time," *W. O. Gantry and G. B. Seaborn, Oak Ridge Gaseous Diffusion Plant.*

"Effect of Thermal Neutron Irradiation on Thermocouples and Resistance Thermometers," *C. W. Ross, Leeds & Northrup.*

Friday Afternoon

Design of Systems and Instruments

"Digital Computers for Use in Nuclear Power Applications," *J. Prades and Y. Panis, Ramo-Wooldridge, CEAE.*

"Automatic Self-Testing of Reactor Monitoring Systems," *D. Fitzgerald, Bendix.*

"Criteria for Transistorization," *E. B. Hubbard, General Electric.*

"Nuclear System Design for Reliability," *J. L. Cockrell, J. H. Magee, and B. S. Magee, and V. S. Underkoffler, Leeds & Northrup.*

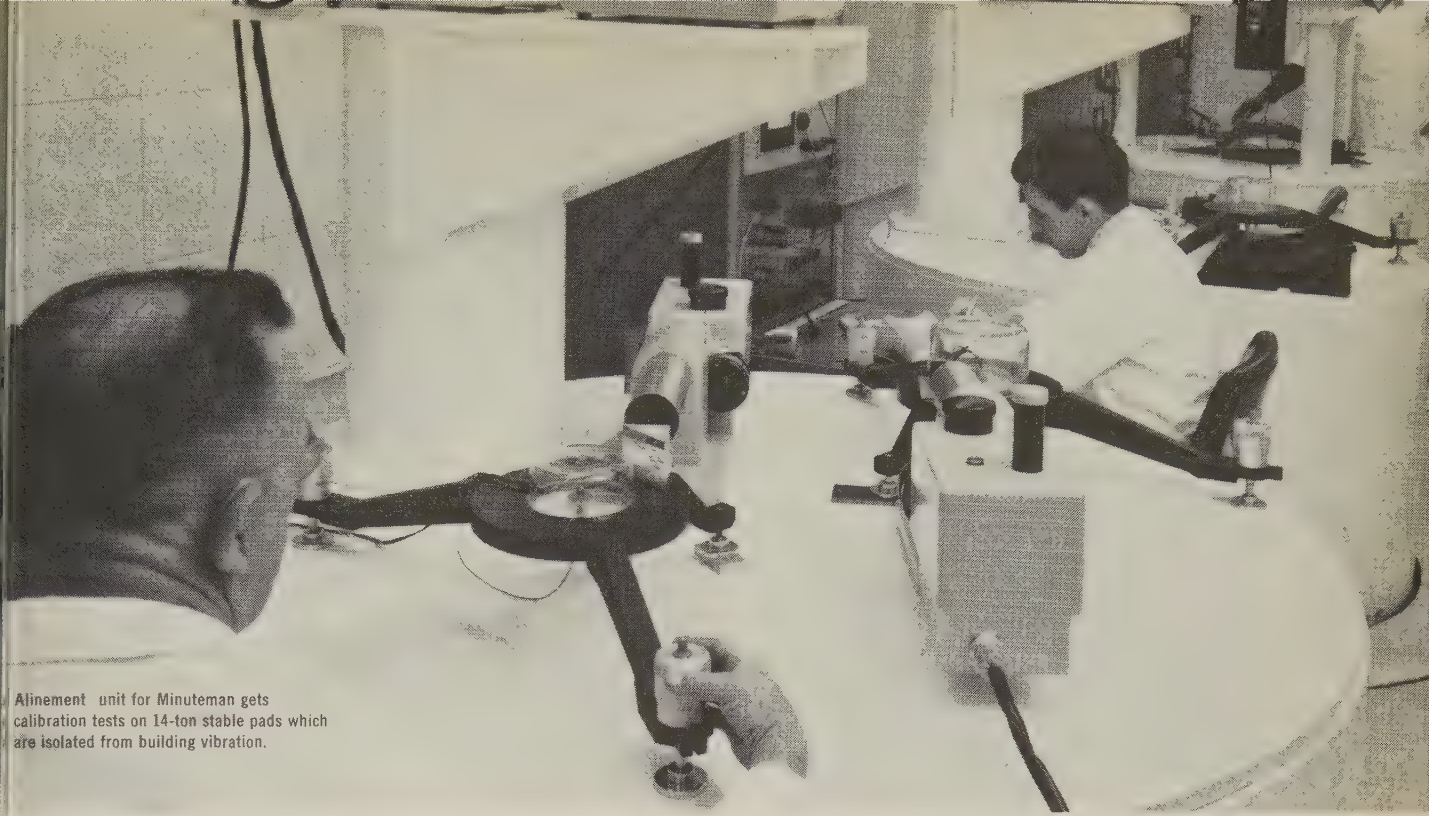
National Symposium on Space Electronics and Telemetry

Johnson Gymnasium, University of New Mexico, Albuquerque, September 6–8, 1961

The IRE Professional Group on Space Electronics and Telemetry will hold its sixth National Symposium in Albuquerque, N. M., on September 6–8. With the cooperation of the University of New Mexico, the Symposium will convene at the Johnson Gymnasium on the University campus. This year's program, consisting of both technical papers sessions and exhibits by electronics manufacturers, will emphasize technological advances and new design philosophies in the fields of space electronics and communications.

The program is organized around six technical sessions in which a total of approximately 28 papers will be presented. Chairmen of the technical sessions, who are responsible for outstanding achievements in their particular technical fields, have each been given the responsibility of soliciting and selecting the papers for their respective sessions. Since both the speakers and their subjects have been selected by the sessions chairmen, the quality and relevancy of the technical material in each session is assured. Each session has been organized to appeal to a large cross section of persons expected to attend the symposium; therefore, no concurrent sessions are planned. By conducting single technical sessions, it has been possible to reserve time on the first day of the Symposium for exhibitors to attend the sessions. By concluding the afternoon session early on the first day, those in attendance will be given time for an orientation tour of the exhibits.

In addition to the technical sessions and exhibits, many social events are planned. These will include the official luncheon, to be held at noon on the first day, and an industry-sponsored cocktail party, to be held at the Cole Hotel on Thursday evening, September 7. A number of interesting activities are being planned for the wives of symposium attendees. These will include



Alinement unit for Minuteman gets calibration tests on 14-ton stable pads which are isolated from building vibration.

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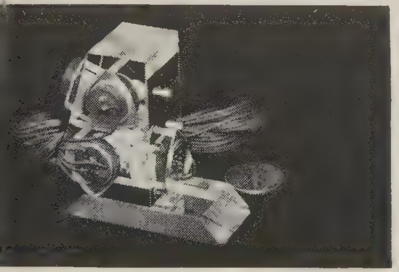
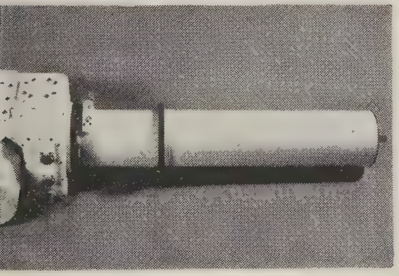


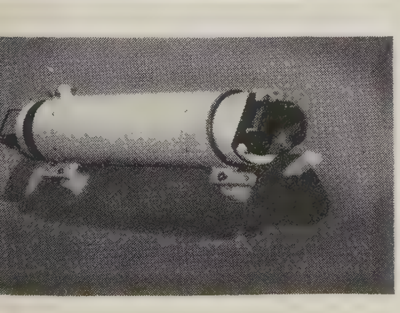
***MINUTEMAN**

Alinement Unit for the Autonetics Division of North American Aviation, Inc. These units establish the vertical reference of Minuteman missile . . . level detectors sense local vertical to an accuracy better than 1 second of arc. The quartz prisms on which the detectors are mounted have angular tolerances of less than 2 seconds of arc and surface flatness of ¼ wavelength of light.



***NIKE-ZEUS**

Optical assembly for Bell Telephone Laboratories. For check of Nike Zeus radar alignment, the tracking system in which this assembly is used has a dynamic accuracy of better than 4 seconds of arc . . . can be adapted to operate in any part of the spectrum from the ultraviolet to the far infrared.



***POLARIS**

Optical deviator for Marine Equipment Department of Nortronics, a division of Northrop Corp. This electro-optical system checks the alignment of the navigation system of the Polaris bearing submarine. It deviates light 180 degrees and maintains accuracy of 2 seconds of arc even in severe vibration, shock and changing temperature environment.

Precision optics, electronics and **mechanics** are being combined at Texas Instruments into new high-accuracy alignment, calibration and tracking systems for advanced programs such as Minuteman, Polaris and Nike-Zeus. This capability began in 1956 when TI integrated complete optical facilities and the skills of veteran craftsmen with the company's total corporate capability which includes development of complex military electronic and mechanical apparatus plus basic and applied research and manufacture of ultra-pure optical materials and detectors. This unique technology has now been extended into the fields of navigation, stabilization, detection, tracking, communications and energy conversion. For information on your specific electro-optical requirements, contact MARKETING DEPARTMENT.

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some tours of the historical, cultural, and scenic points of interest in the Albuquerque area.

This year's Symposium is being sponsored by the Albuquerque—Los Alamos PGSET Chapter. The Symposium Committee consists of the following: Symposium Officer—Chairman, A. B. Church; Vice-Chairman, R. C. Spence; Secretary, T. L. Pace; Treasurer, T. M. Tinkle; Committee Chairmen—Papers, Dr. B. L. Basore; Exhibits, C. H. Schmit; Arrangements and Social, W. T. Smith; Women's Activities, Mrs. T. E. Lommasson; Publicity and Public Relations, L. E. Schultz; and Advisors—R. Creveling, R. P. Noble, W. C. Myre (PGSET Activities), J. C. Shoup, and Dr. A. H. Koschman.

Wednesday Morning, September 6

Session I—Engineering Aspects of Vela Hotel Background Experiments

Chairman: *James Scott, Sandia Corp., Albuquerque, N. M.*

"World-Wide Tracking Networks," *R. G. Hester, Aerospace Corp., Los Angeles, Calif.*

"Electrical and Mechanical Limitations of Photomultipliers for Space Applications," *Dr. A. J. Northrop, Los Alamos Scientific Lab., Los Alamos, N. M.*

"Detector Electronics for Vela Hotel Background Experiments," *J. R. Gillard, Los Alamos Scientific Lab., Los Alamos, N. M.*

"Reliability and Packaging Aspects of Digital Data Handling Circuits," *W. B. Goldrick, Sandia Corp., Albuquerque, N. M.*

Wednesday Afternoon

Session II—Space Oriented Product Development

Chairman: *Conrad Hoeppner, Electronetics., Inc., Melbourne, Fla.*

"A Programmable Omnidrive Multiplexer for High-Speed PCM Systems," *D. N. Dry, Sonex, Inc., Philadelphia, Pa.*

"High Speed Solid State PCM Encoder," *T.R.A. Gregory, Sonex, Inc., Philadelphia, Pa.*

"Digilock Telemetry System for the Air Force Special Weapons Center's Blue Scout, Jr.," *R. M. Jaffe, Space Electronics Corp., Glendale, Calif.*

"A Multichannel Industrial Telemeter Using Magnetic Logic Elements," *J. H. Porter, Crestmont Electronics, Burbank, Calif.*

"On Line Computer Reduction of Telemetry Data," *W. F. Kamsler, Epsco-West, Anaheim, Calif.*

Thursday Morning, September 7

Session III—Satellite Relay Communications

Chairman: *Albert Feiner, Rome Air Dev. Ctr., Rome, N. Y.*

"Passive Satellite Communications Concepts," *J. E. McFee, Rome Air Dev. Ctr., Rome, N. Y.*

"A Global Satellite Communications System," *L. C. Hunter and J. A. Stewart, General Telephone and Electronics Labs., Inc., Menlo Park, Calif.*

"Terminal Equipment Characteristics for a Satellite Communication System," *H. A. George and D. R. Campbell, IT&T Federal Labs., Nutley, N. J.*

"Space Propagation Studies at Optical Frequencies Using Laser Sources," *R. K. Long, E. K. Damon, and C. H. Boehnker, Antenna Lab., Ohio State University, Columbus, Ohio.*

Paper to be announced.

Thursday Afternoon

Session IV—Techniques for Space Communications

Chairman: (*To be Announced.*)

"Lunaberg Lenses for Space Communications," *C. H. Walter and R. C. Ruddick, Ohio State University, Columbus, Ohio.*

"Use of Phased Arrays as High Gain Low Noise Antennas for Space Communications, *J. W. Eberle, Ohio State University, Columbus, Ohio.*

"The Behavior of an H. F. Antenna in the Ionosphere," *A. R. Molozzi and J. R. R. Richardson, Defence Research Telecommunications Establishment, Ottawa, Ontario.*

"Decreasing the Threshold in FM by Frequency Feedback," *L. H. Enloe, Bell Telephone Labs., N. J.*

"Design and Performance of a Broad Band FM Demodulator with Frequency Feedback," *C. L. Ruthroff, Bell Telephone Labs., Red Bank, N. J.*

Friday Morning, September 8

Session V—Techniques for Space Research

Chairman: *Dr. H. P. Kalmus, Diamond Ordnance Fuze Labs., Washington, D.C.*

"The Statistical Approach to FM Radar," *Dr. W. K. Saunders, Diamond Ordnance Fuze Labs., Washington, D. C.*

"Atomic Clocks and their Applications," *F. H. Reder, USASRDL, Ft. Monmouth, N. J.*

"Power Sources for Space Applications," *N. D. Wheeler, General Electric Co., Advanced Electronics Ctr., Ithaca, N. Y.*

"Nuclear-Booster Data Acquisition and Checkout System," *R. Brooks, Martin Co., Denver, Colo.*

Friday Afternoon

Session VI—Data Handling in Space Communication

Chairman: *Walter E. Brown, Jr., Jet Propulsion Labs., Pasadena, Calif.*

"Bit Rate Generator and Raw Data Conditioner," *S. C. Steely, Sandia Corp., Albuquerque, N. Mex.*

"Sampled Data Telemetry for Satellite Applications," *C. M. Kortman, Lockheed Missiles and Space Div., Palo Alto, Calif.*

"Telemetering IR Data from the Tiros II Meteorological Satellite," *Davis, et al., NASA Goddard Space Flight Ctr., Greenbelt, Md.*

"An Integrated Communications System for Space Vehicles," *R. A. Schomberg, G. U. Bishop, and R. H. Hardin, Martin Co., Denver, Colo.*

"A Preliminary Design for a Planetary Landing and Observation Package," *L. J. Nolte, A. T. Owens, and R. L. Sax, Hughes Aircraft Co., Culver City, Calif.*

Ninth Annual Engineering Management Conference

HOTEL ROOSEVELT, NEW YORK, N. Y., SEPTEMBER 14–15, 1961

The 9th Annual Joint Engineering Management Conference will be held at the Hotel Roosevelt, New York, N. Y., on September 13–14, 1961.

This Conference is sponsored by the American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Society of Civil Engineers, American Institute of Industrial Engineers with the cooperation of the American Institute of Chemical Engineers, American Institute of Mining, Metallurgical and Petroleum Engineers, The Institute of Radio Engineers, and the local sections of these societies.

The presentation of the 1961 Henry Laurence Gantt Medal to Col. L. H. Ulrick will be made at luncheon on Friday, September 15.

The Conference will be devoted entirely to the problems facing engineering managers. The focus of the meetings will be upon the personal development, job environment and professional goals of the engineer, and the function of the engineering manager in these areas.

This Conference, which is in its ninth year, is devoted solely to the management of engineering activity, a subject becoming increasingly important as technology expands. It will afford an opportunity for managers and engineers to participate in discussions in which the emphasis is on the improvement of the art and practice of the direction of technological effort in all fields.

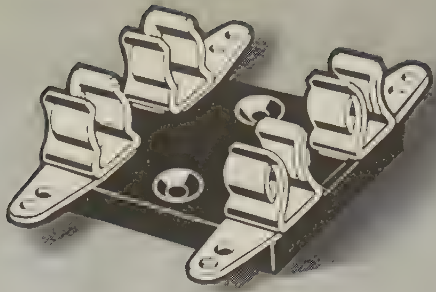
Most papers will be available at the Conference, and the final listing of available technical papers will be found in the November issue of *Mechanical Engineering*, which will contain an account of the Conference. Papers can be obtained from the ASME Order Department, 29 West 39 St., New York 18, N. Y.

Thursday, September 14

Session I—Advanced Techniques and Engineering Management

"PERT, A Technique for Management," *K. M. Tebo, Director of Management Control and Analysis, A. C. Spark Plug Div. of General Motors Corp., Milwaukee, Wis.*

"Statistics and/or as Tools for Engineering Managers," *Dr. C. F. Kossack, Research Manager, Statistics and Operations Research,*



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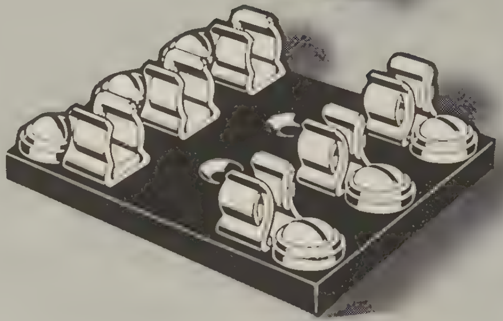

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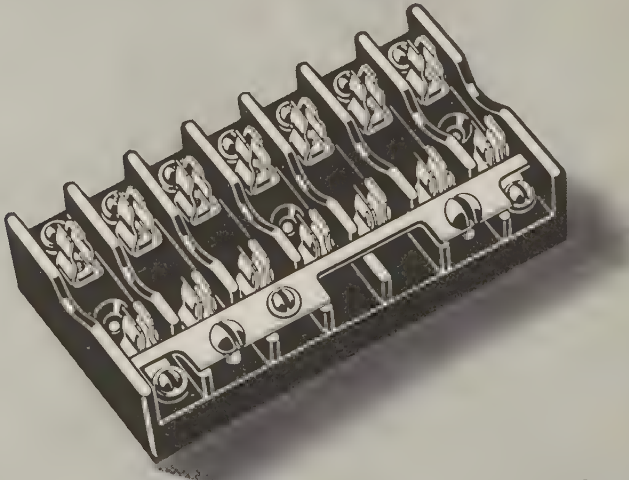

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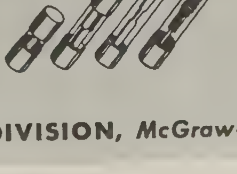

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"Increased Profits Through Application of Computer Technology," *Dr. W. W. Eaton, Vice President and Director, C-E-I-R, Alexandria, Va.*

Thursday Luncheon

"The Changing Personality of Today's Engineer," *I. N. Palley, President, ITT Federal Labs., Nutley, N. J.*

Thursday Afternoon

Session II—The Expanding Interests of Engineering

"Problems of Management in Foreign Countries," *G. Browne, Editor, McGraw-Hill Publication, "Industria," New York, N. Y.*

"The Economic Environment in Which Engineers Work," *Dean C. Madden, Lehigh University, College of Business Administration, Bethlehem, Pa.*

Friday Morning, September 15

Session III—Human Values in Management

"Human Relations Problems in the Management of Engineering," *Professor (Emeritus) E. H. Schell, Massachusetts Institute of Technology, Cambridge.*

"The Personal Approach in Dealing with Technical People," *H. L. Cox, Vice President (Retired), Corn Products Corp., Chicago, Ill.*

"Enhancing Human Values During Institutional Change," *Dr. F. F. Bradshaw, Management Consultant, New York, N. Y.*

Friday Afternoon

Session IV—Management of Research

"Problems of Administration of Research and Development," *Dr. H. C. Vernon, Director, Engineering Department Experimental Station, E. I. duPont de Nemours and Co., Wilmington, Del.*

"Management of Research and Development Personnel in an Industrial Laboratory," *Dr. R. B. Mears, Assistant Vice President, Applied Research, United States Steel Corp., Pittsburgh, Pa.*

Industrial Electronics Symposium

Bradford Hotel, Boston, Mass., September 20–21, 1961

Stressing electronic manufacturer-industrial user cooperation, the 1961 Joint Industrial Electronics Symposium will attempt to foster a closer liaison and better understanding between the two groups. The two-day session will be held in Boston's Bradford Hotel on Wednesday, September 20, and Thursday, September 21, 1961.

Joint sponsors of the Symposium are the IRE Professional Group on Industrial Electronics (PGIE), AIEE, and ISA.

Symposium General Chairman is W. M. Trenholme of MIT. His steering committee includes: Program Chairman, R. K. Jurgen of Electrical Engineering; Arrangements Chairman, D. J. La Cerda of Badger Manufacturing Company; Finance Committee Chairman, D. Z. Breck of Lynn Electric Company; and Publicity Committee Chairman, H. O. Painter, Jr., of General Radio Company.

Luncheon speakers for the Symposium are Harold Chestnut of the General Engineering Laboratory, General Electric Company, Schenectady, N. Y., and Dr. J. F. Reintjes, Director of the MIT Electronic Systems Laboratory. On Wednesday noon, Dr. Reintjes will discuss, "Educating Engineers for Careers in Industrial Electronics." Mr. Chestnut, who will speak on Thursday, has chosen for his topic, "The Role of Electronics in Industrial Automatic Control."

The panel discussion session, with W. E. Vannah of Foxboro Company as Moderator, will cover many problem areas related to the use of electronic equipment throughout industry. Panel members representing various segments of industry will discuss topics such as: reliability of current industrial electronic equipment, trends in future equipment design, better methods for liaison between users and manufacturers, and preventive maintenance. Audience participation will be encouraged.

Advance programs, registration forms, and hotel reservation information may be obtained by writing to D. J. La Cerda, Badger Manufacturing Company, 363 Third St., Cambridge, Mass.

Program Chairman R. K. Jurgen has announced the following tentative program:

Wednesday Morning, September 20

Session I—Measuring Techniques for Industry

Chairman: *Dr. C. W. Clapp, Consulting Physicist, Instrument Dept., General Electric Co., West Lynn, Mass.*

"Non-Contact Dimensional Measurements by Optical and Electronic Techniques," *C. D. Bryant, Senior Engineer, Allen B. DuMont Labs., Clifton, N. J.*

"Non-Destructive Testing of Materials and Components," *P. Dick, Manager, Measurements and Environments Engrg., Missile and Space Vehicle Dept., General Electric Co., Philadelphia, Pa.*

"Moisture Measurement in Industry," *H. W. Gebele, Project Engineer, The Foxboro Co., Foxboro, Mass.*

"Analytical Instrumentation for Process Monitoring and Control," *H. J. Maier, Product Specialist in Process Chromatography, Instrument Div., Perkin-Elmer Corp., Norwalk, Conn.*

"Electronic Devices for Measuring Flow," *D. R. Lynch, Product Manager, Flowmeter Div., Fischer & Porter Co., Warminster, Pa.*

Wednesday Afternoon

Session II—Digital and Analog Techniques in Industry

Chairman: *F. W. Atkinson, General Engineering, Owens-Corning Fiberglas Co., Toledo, Ohio.*

"Digital Control Techniques Applied to Automatic Weighing Processes," *D. W. Kennedy, Senior Applications Engineer, and C. W. Hibscher, Chief Materials Handling Engineer, Toledo Scale, Div. of Toledo Scale Corp., Toledo, Ohio.*

"Digital Control of In-Line Blending," *C. A. Hill, Chief Systems Project Engineer, Packard Bell Computer, Los Angeles, Calif.*

"Blending by Analog Computers," *H. H. Roth, Market Manager, Special Systems Div., Minneapolis-Honeywell Regulator Co., Pottstown, Pa.*

"Computer Control Practices and Preferences in Industry," *W. Mikelson, General Electric Co., Schenectady, N. J.*

"Electronic Guidance and Remote Control for Coal Mining," *K. L. Shrider, Electronic Development Engineer, Reliance Electric and Engineering Co., Cleveland, Ohio.*

Thursday Morning, September 21

Session III—Power Conversion Techniques

Chairman: *C. H. Chandler, Manager, Electronic Process Development, Gillette Safety Razor Co., Boston, Mass.*

"D-C to A-C Power Conversion by Semiconductor Inverters," *E. J. Duckett, Project Manager, New Products Lab., Westinghouse Electric Corp., Pittsburgh, Pa.*

"An A-C Electric Transmission/Drive for Turbine Powered Vehicles," *G. E. Pinter, Senior Application Engineer, Jack & Heintz, Inc., Cleveland, Ohio.*

"A 50 KVA Adjustable Frequency 24-Phase Controlled Rectifier Inverter," *C. W. Flairty, Electric Power Conversion Engrg., Electrical Engrg. Lab., General Electric Co., Schenectady, N. Y.*

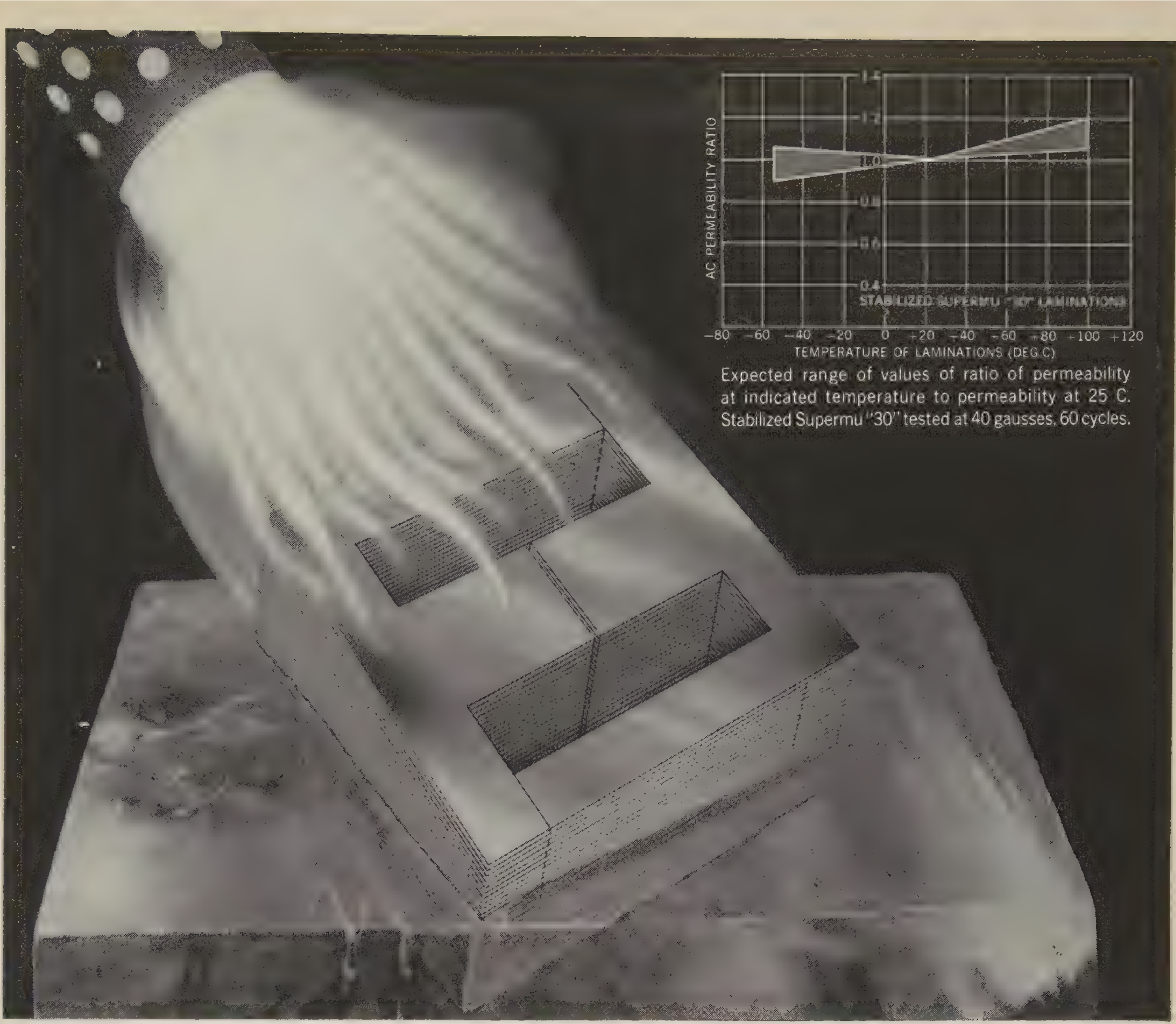
"Trends in Ultrasonic Machining Techniques," *R. P. Curtis, Senior Staff Member, Commercial Apparatus & Systems Div., Raytheon Co., Norwood, Mass.*

"Thermoelectric Applications to Industrial Problems," *Dr. J. C. R. Kelly, Director, Central Technical Services, Research Labs., Westinghouse Electric Corp., Pittsburgh, Pa.*

Thursday Afternoon

Panel Discussion of Manufacturer-User Problems. Moderator: *W. E. Vannah, Advanced Engrg. Planning, The Foxboro Co., Foxboro, Mass.*

Panel Members: *E. S. Ida, Instrument Consulting Group, E. I. Dupont de Nemours & Co., Wilkington, Del.* (Chemical Processing); *R. F. Sorenson, Staff Electrical Engineer, St. Regis Paper Co., Jacksonville, Fla.* (Paper Mills); *M. Fox, Chairman, National Machine Tool Builders Association, Lapointe Machine Tool Co., Hudson, Mass.* (Machine Tools); *Representative from the Utility Industry; Representative from the Steel Industry.*



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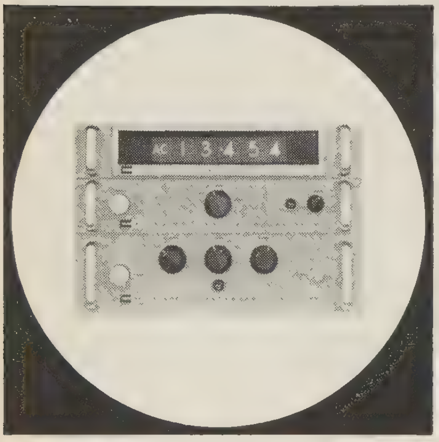

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Industrial Engineering Notes*

ASSOCIATION ACTIVITIES

Upon recommendation of the Educational Coordinating Committee, under Chairman Ben Edelman, and with the approval of all five divisions, the Board of Directors appropriated funds for publication of an electronics career booklet for the guidance of high school students. The Institute of Radio Engineers, Mr. Edelman said, will help finance the preparation of the informational material. Following publication, copies will be distributed among some 28,000 high schools throughout the country and also will be made available on a cost basis to member-companies for additional distribution. The publication is planned by late summer or early fall. . . . **Treasurer L. F. Muter was re-elected for the 26th year following presentation of a silver service in recognition of his service to the Association.** Mr. Muter was first elected RMA treasurer in 1931–32 and has served continuously in this position since 1938–39. Re-elected Senior Vice President was R. S. Bell, of the Consumer Products Division; and as Vice Presidents S. R. Curtis, for the Military Products Division; W. S. Parsons, for the Parts Division; and Ben Adler, for the Industrial Electronics Division. G. W. Keown, Vice President-Sales, Tung-Sol Electric, Inc., was elected both Vice President and Chairman of the Tube and Semiconductor Division. Two new Directors were elected. They are: G. B. Mallory, President of P. R. Mallory and Co., Inc., for the Parts Division, and L. M. Sandwick, Vice President of Pilot Radio Corp., for the Consumer Products Division.

Executive Vice President J. D. Secrest was re-elected for his twelfth term, and General Counsel J. B. Olverson for his third. Two new departmental Directors were elected by the Board. W. G. Tuttle, Vice President of American Bosch Arma Corp., was named head of the Industrial Relations Department, and T. P. Collier, president of Motorola Overseas Corp., was named Chief of the International Department. Re-elected were F. R. Lack as Director of the Engineering Department, F. W. Mansfield as Head of the Marketing Data Department, and C. P. Young as Director of the Military Relations Department. . . . **An estimated 76 per cent of all engineers and scientists employed by the U. S. electronics industry are supported by government funds, according to a survey recently conducted by the EIA Marketing Data Department with the cooperation of the Department of Defense.** The remaining 24 per cent is engaged in commercially supported activities. The report, which has been sent to all participating companies and to the Defense Department, discloses that there are an estimated 155,000 engineers and scientists performing electronics work in all areas. Eighty-three per cent, or 128,000, are employed by industry, while eight per cent are working for the Federal Government and five per cent are doing research work for universities and nonprofit organizations. The remainder comprises independent consultants, engineers and scientists between jobs, and those not identifiable by area of electronic activity. "The large number of engineers and scientists employed by the electronics industry constitutes one of our country's most vital national resources," EIA President L. Berkley Davis said in announcing results of the survey. "It is important that officials of the Defense Department, military contractors, and other industry leaders are sufficiently informed as to the distribution of this technical manpower among government and commercially supported activities in order to avoid possible adverse effects of major shifts in defense programming. This survey was conducted for the purpose of providing this information to industry and the Department of Defense." EIA had the cooperation of J. M. Bridges, Director of Electronics, Office of the Secretary of Defense, in conducting the survey. Distribution of the complete report has been restricted to manufacturers who provided information on their own employment of engineers in response to an EIA questionnaire.

GOVERNMENTAL AND LEGISLATIVE

The Federal Communications Commission ruled that international communication common carriers should handle establishment of commercial satellite communications systems, to the exclusion of manufacturing firms. "A joint venture composed only of existing common carriers engaged in international telephone and telegraph communication is deserving of consideration and exploration as an effective means of promoting the orderly development of such a system," the FCC said in a First Report in its inquiry into administrative and regulatory problems of the space satellite communications systems (Docket 14024). "We fail to see why ownership participation by the aerospace and communications equipment industries will be beneficial or necessary to the establishment of a satellite communication system to be used by the common carrier industry," the Commission notice stated. The Commission announced a June 5 meeting in Washington of all in-

(*Continued on page 36A*)

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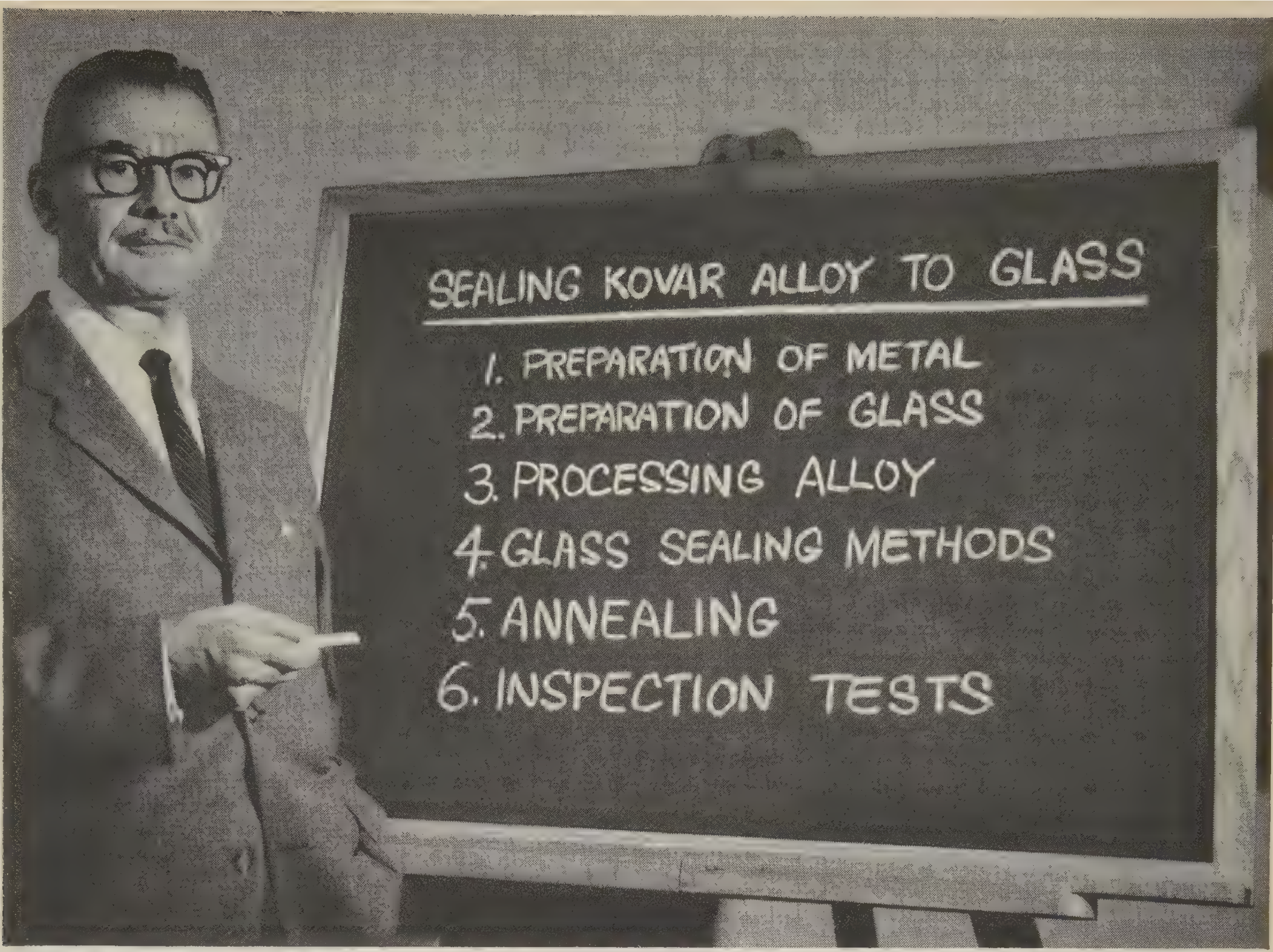
* The data on which these NOTES are based were selected by permission from *Weekly Reports*, issues of May 29, June 12 and 19, 1961, published by the Electronic Industries Association, whose helpfulness is gratefully acknowledged.



Engineering hints from Carborundum

6 steps to better glass-to-metal seals with KOVAR® Alloy

KOVAR® is the original iron-nickel-cobalt alloy with correct thermal expansion characteristics for making seals with several hard glasses. Procedures for obtaining a satisfactory seal—with optimum production yields—will vary according to the nature of the end product. This may range from large electron tubes to the smallest semi-conductor devices. The following hints typify recommendations for the more critical electron tubes; they can be modified for other products according to need.

1. KOVAR should be scratch-free. Polish with 180-grit aluminum oxide cloth, followed by 260-grit—never emery or carbide. Round edges of edge-type seals with a radius of about half metal thickness. Sand-blasted matt finish, using pure alumina, is preferable for butt type seals.
2. REMOVE DUST FROM GLASS with lint-free cloth. Rinse in 10% hydrofluoric acid solution, then in running tap water, finally in distilled water. Dip in methanol and hot air dry.
3. CLEAN KOVAR prior to sealing by trichlorethylene vapor degreasing, immersion in concentrated HCl, followed by rinses in tap and distilled water. Methanol dip and hot air dry. Heat treat in wet hydrogen atmosphere.
4. SEALING EQUIPMENT includes gas-oxygen burner and glass lathe. Oxidize surfaces by heating metal and glass to 850° C in air. Bring parts together by pressure. For strong seal, glass edge should approach 90° angle where it meets KOVAR alloy.
5. ANNEAL SEAL using flame or furnace program, advancing to annealing temperature for 30 mins. Reduce to 50° C below strain point at 1° per minute, then 10° per minute to room temperature.
6. INSPECTION may include stress analysis by polariscope viewing or other method. Examination under 10x to 15x magnification should show that glass is free from excessive bubbles. Glass color should be grayish or mouse brown.

FIND OUT ABOUT KOVAR—WHERE IT IS USED AND WHY

Bulletin 5134 gives data on composition, properties and applications of KOVAR Alloy. For data on sealing procedures, ask also for Technical Data Bulletin 100-EB6. Write Dept. P-81, Latrobe Plant, Carborundum Co., Latrobe, Pa.

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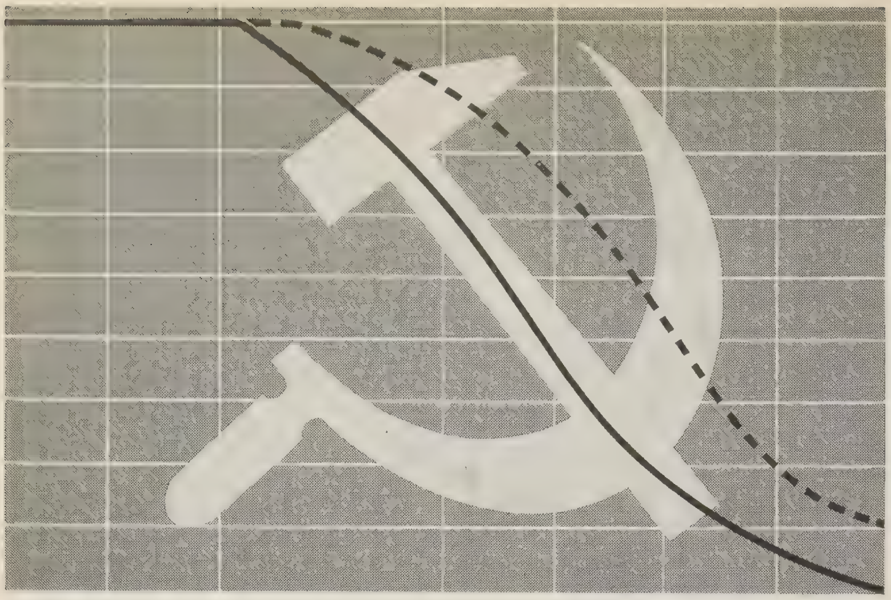

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Let official Soviet publications keep you informed of Russian technical developments behind the Iron Curtain. Four original Soviet journals are available to you in English, cover-to-cover translations. The ISA *Soviet Instrumentation and Control Series* is sponsored by the Instrument Society of America under a grant from the National Science Foundation. Now in its third year, this series affords you an excellent means of charting Russian activities in automatic control, measurement techniques and instrumentation. The translated journals are:

Automation and Remote Control
Avtomatika i Telemekhanika)—Articles on all phases of automatic control theories and techniques. Published monthly by the Academy of Sciences, U.S.S.R. *('57, '58, '59 and '60 issues available)*

Instruments and Experimental Techniques
(Pribory i Tekhnika Eksperimenta)—Bi-monthly published by the Academy of Sciences, U.S.S.R. Articles relate to function, construction, application and operation of instruments in various fields of experimentation. *('58, '59 and '60 issues available)*

Measurement Techniques
(Izmeritel'naia Tekhnika)—Published monthly by Academy of Sciences, U.S.S.R. Particularly interesting to those engaged in study and application of fundamental measurement. *('58, '59 and '60 issues available)*

Industrial Laboratory
(Zavodskaya Laboratoriya)—Published monthly by the State Scientific-Technical Committee of the Council of Ministers, U.S.S.R. Presents articles on instrumentation for analytical chemistry and physical and mechanical methods of material research and testing. *('58, '59 and '60 issues available)*

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Industrial Engineering Notes

(Continued from page 34A)

ternational common carriers and some government agencies to discuss plans for the system. Attendance was by invitation only. . . . **A second inquiry into the allocation of international radio frequencies for domestic and foreign space programs has been initiated by the Federal Communications Commission.** The FCC's Second Notice of Inquiry in Docket 13522 sets forth preliminary views of the United States regarding international allocations. The proposals would provide for a communication satellite space service, a space research service, a meteorological satellite space service, initial requirements for an aeronautical mobile route service operating in space, and the telemetry, command, guidance, and tracking functions associated with the proposed services. The views were developed by the Commission in consultation with the Office of Civil and Defense Mobilization and the Interdepartmental Radio Advisory Committee. Comments filed by industry in the FCC's First Notice of Inquiry were also considered. The Commission requested industry comments in the second inquiry by June 23. The proposals will be modified and sent to the State Department for recommended use by U. S. representatives in discussions with other countries.

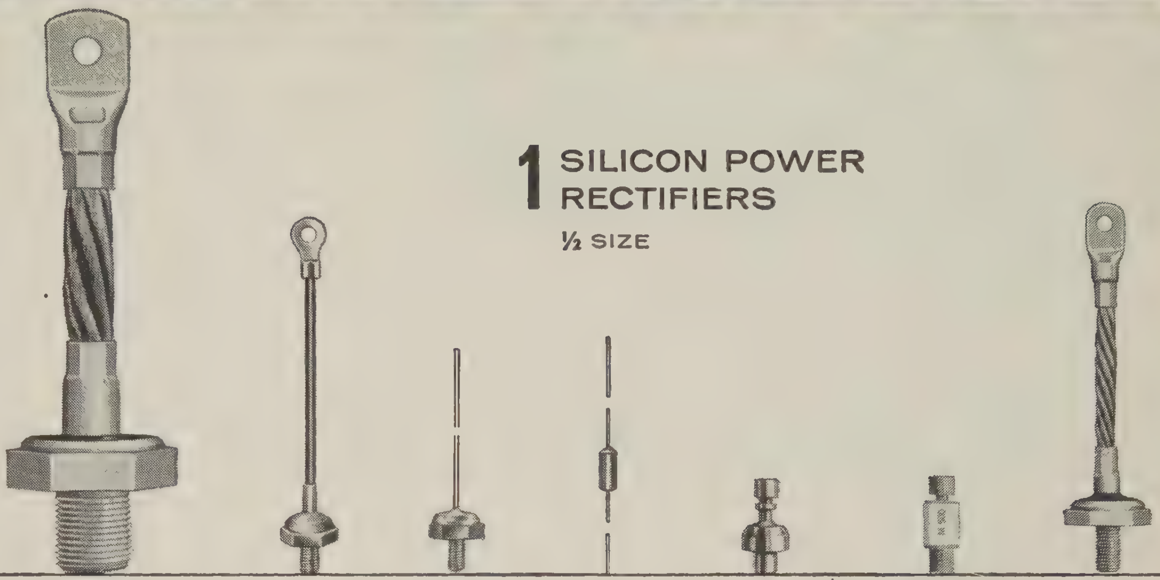
INDUSTRY MARKETING DATA

Factory sales of transistors fell off during April, but year-to-date sales totals stayed well ahead of those for the same period last year. The Marketing Data Department's compilation showed 15,072,064 units worth $27,388,278 sold at the factory in April, compared with 15,129,273 worth $29,815,291 sold in March. For the first four months of this year, sales totals stood at 55,655,696 transistors valued at $105,858,361. To the end of April last year, the figures were 41,047,034 units and $101,444,855.

MILITARY AND SPACE

A prototype of the Navy's navigation satellite system may be in working order by the fall of 1962, it was recently reported. The Transit system, which is intended to provide world-wide navigation aid with four satellites, will have cost an estimated $75 million by that date. The Navy's fiscal 1962 budget carries $4.8 million for procurement of boosters and satellites and another $17 million for research, development, test and evaluation. Work of the Applied Physics Laboratory of Johns Hopkins University was reported to have resulted in a prototype operational design for a 90-pound Transit satellite. The original experimental satellite was to weight 250 pounds. It was believed that the final design specification will not be announced until in-flight tests of prototypes are completed.

Now...5 designers' lines from Sarkes Tarzian



1 SILICON POWER RECTIFIERS

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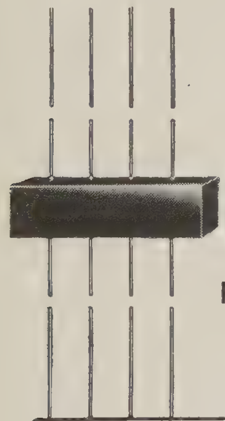

2 MODULAR SILICON RECTIFIERS

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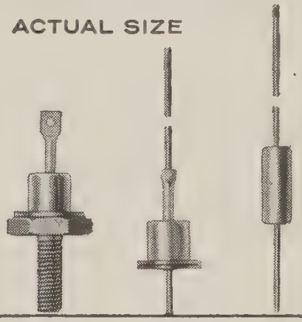
For printed circuits or terminal strips—2, 3, and 4 section modules of 500 ma diodes, 100 to 600 piv.

3 SILICON VOLTAGE REGULATORS

ACTUAL SIZE



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4 HIGH VOLTAGE SILICON CARTRIDGE RECTIFIERS

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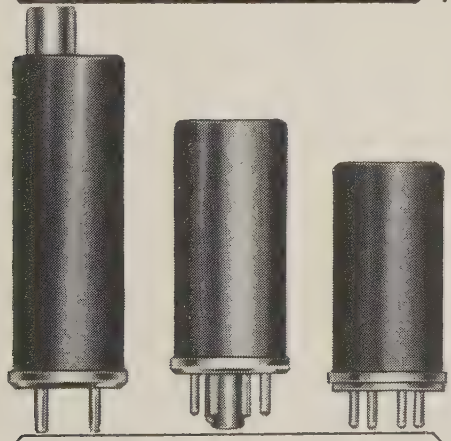

5 SILICON TUBE REPLACEMENT RECTIFIERS

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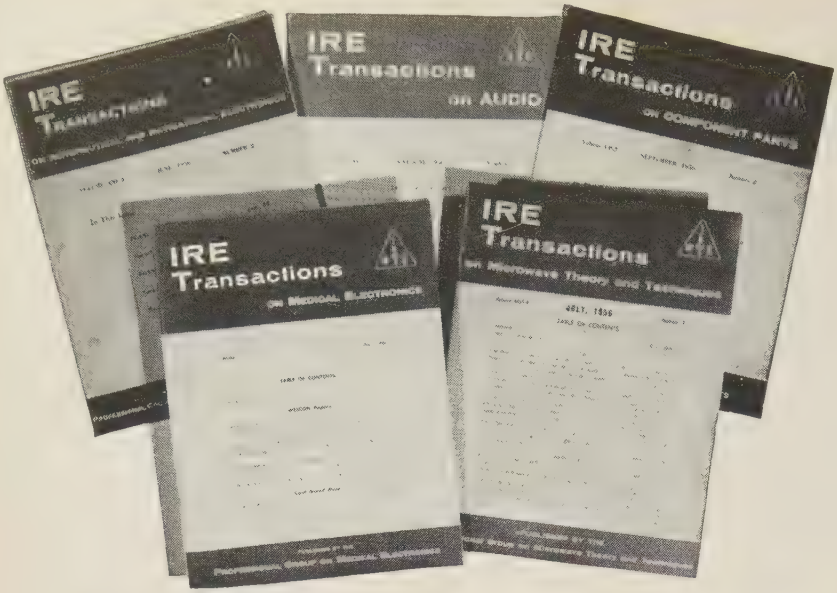
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Professional Group on Electron Devices

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It is not surprising, therefore, that a great deal of effort has been directed toward improvements in electron tubes and semiconductors, and that the resulting advances have received close and widespread attention. The rewards have been impressive. Work on cathode-ray tubes, for example, was a prime factor in the successful evolution of television. The advent of klystrons, magnetrons and traveling-wave tubes made possible the development of equipment capable of operating in the microwave portion of the spectrum. The transistor opened up a whole new era of solid-state electronics.

IRE members who wished to keep abreast of the many developments in this important and rapidly moving field were greatly aided by the formation of the IRE Professional Group on Electron Devices in 1951. The Group immediately began to organize technical sessions in its field at many of the national meetings held during the year. This was followed by the formation of Group Chapters throughout the country which collaborate with IRE Sections to sponsor meetings locally.

Perhaps of greatest importance, the Group began publishing its own technical publication, called Transactions, which is distributed free to all members who pay the assessment fee of $3.00. The Transactions is now issued bimonthly to over 5000 members, and has become an invaluable source of information on the latest technical developments in the field of electron devices.

Ernst Weber
Chairman, Professional Groups Committee

Professional Group Meetings

Aerospace and Navigational Electronics

Akron—May 16

"Inertial Guidance and Components," B. Lichtenstein, Kearfott Division of GPI, Little Falls, N. J.

Boston—May 15

"Air Traffic Control or . . . Chaos," V. Kayne, AOPA; F. McDermott, ATCA; E. Bechtold, ALPA; J. O'Brien, FAA; Dr. Valley, MIT.

Boston—December 13

"The Radar Joint Use Programs," and "Joint Use Compatibility Problem," E. R. R. Warner, USAF; C. Brackett, Mitre Corp.

Florida West Coast—May 17

"Collision Avoidance," Capt. Packard, Federal Aviation Agency, Washington, D. C.

Philadelphia—April 18

"Air Traffic Control Displays," J. D. Woodward, RCA, Camden, N. J.

Philadelphia—February 14

"System Engineering of the 433L Weather Observing and Forecasting System," F. Himmer, Philco Corp., Philadelphia.

Antennas and Propagation

Boston—May 9

"Avco Natural Communications System," G. E. Hill, Avco, Wilmington, Mass.

"An HF Magnetically Coupled Helical Antenna," G. Ploussios, Chu Associates; N. H. Thompson, Portsmouth Naval Shipyard.

Los Angeles—May 11

"The Determination of the Antenna Temperature of a Large Paraboloid," D. Schuster, Jet Propulsion Lab., Pasadena, Calif.

San Francisco—May 10

"HF and VHF Log-Periodic Antennas," Dr. R. Justice, Granger Associates, Palo Alto, Calif.

Antennas and Propagation Microwave Theory and Techniques

Buffalo-Niagara—March 8

"High Power Microwave Research," R. C. Bietz, Cornell Aeronautical Lab., Cheektowaga, N. Y.

Orange Belt—May 11

"Symposium on Frequency Independent Antennas," Dr. P. E. Mayes, University of Illinois and Dr. R. H. DuHamel, Hughes Aircraft Co.

Philadelphia—May 11

"Designing Large Aperture Antennas Using Digital Computers," J. H. Morrissey, Philco, Philadelphia.

"Microwave Losses in Unsaturated Ferrate Materials," A. C. Nash, RCA, Moorestown.

San Diego—May 9

"TWT Characteristics Affecting Modern Microwave Antenna and System Design," B. Highstreet, Hughes, Los Angeles.

Audio

Albuquerque-Los Alamos—March 15

"A Description of KHFM Transmitting Facilities," D. Annett, Radio Station KHFM.

D. Annett and E. Koerner conducted a tour of the station facilities with a complete description of all station operations.

Philadelphia—April 26

"The New FCC Regulations on FM Stereo," R. Bolgiano, WDHA-FM, Dover, N. J.

Automatic Control

Los Angeles—May 9

"Inertial Guidance Techniques for Space Applications," B. Keeler, Honeywell Regulator Co., St. Petersburg, Fla.

Pittsburgh—February 22

"Splitting Ergs into Bits," Dr. H. M. Paynter, MIT.

Automatic Control Bio-Medical Electronics

Boston—April 18

"Neurological Servomechanisms," Dr. L. Stark, MIT.

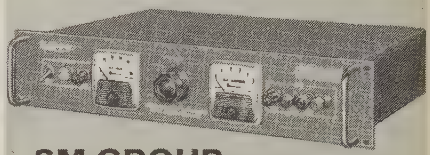
Automatic Control Electronic Computers

Boston—January 18

"Digital Computers in Process Control," L. A. Gould, MIT; S. Dinman and T. Knutrud, RCA.

(Continued on page 40A)

PRECISE, RELIABLE POWER SUPPLIES IN A WIDE CHOICE OF OUTPUT RANGES



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Three rack sizes: 8¾" H, 5¼" H, and 3½" H. Impervious to operational damage: circuit protection is an inherent function of input transformer and regulator characteristics.

3½" PANEL HEIGHT

0.1% REGULATION MODELS	DC OUTPUT RANGE VOLTS	DC OUTPUT RANGE AMPS	0.01% REGULATION MODELS
SM 14-7M	0–14	0–7	SM 14-7MX
SM 36-5M	0–36	0–5	SM 36-15MX
SM 75-2M	0–75	0–2	SM 75-2MX
SM 160-1M	0–160	0–1	SM 160-1MX
SM 325-0.5M	0–325	0–0.5	SM 325-0.5MX

5¼" PANEL HEIGHT

0.1% REGULATION MODELS	DC OUTPUT RANGE VOLTS	DC OUTPUT RANGE AMPS	0.01% REGULATION MODELS
SM 14-15M	0–14	0–15	SM 14-15MX
SM 36-10M	0–36	0–10	SM 36-10MX
SM 75-5M	0–75	0–5	SM 75-5MX
SM 160-2M	0–160	0–2	SM 160-2MX
SM 325-1M	0–325	0–1	SM 325-1MX

8¾" PANEL HEIGHT

0.1% REGULATION MODELS	DC OUTPUT RANGE VOLTS	DC OUTPUT RANGE AMPS	0.01% REGULATION MODELS
SM 14-30M	0–14	0–30	SM 14-30MX
SM 36-15M	0–36	0–15	SM 36-5MX
SM 75-8M	0–75	0–8	SM 75-8MX
SM 160-4M	0–160	0–4	SM 160-4MX
SM 325-2M	0–325	0–2	SM 325-2MX

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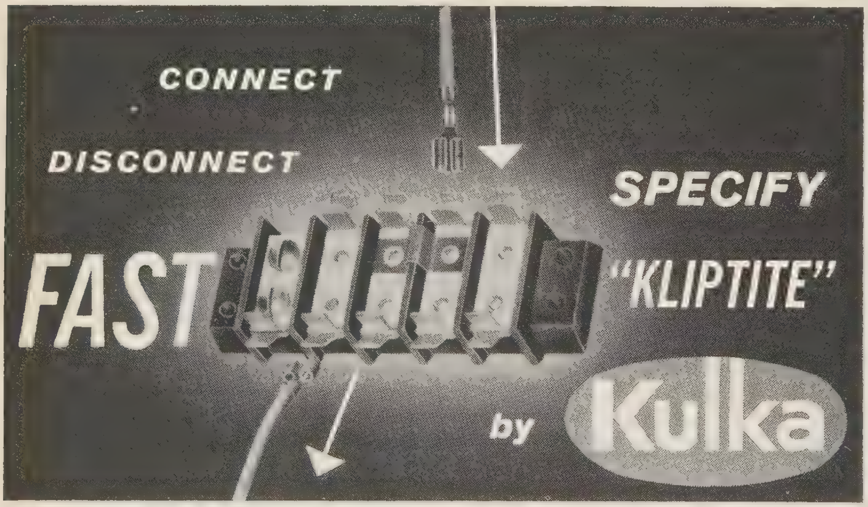

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Professional Group Meetings

(Continued from page 39A)

Fort Worth—May 16

"Twin Gyro Space Vehicle Control," D. F. Sellers, Vought Electronics, Arlington, Tex.

BIO-MEDICAL ELECTRONICS

Philadelphia—March 9

"The Thorner Pulsensor for Taking the Ophthalmic Artery Pressure and Plethysmograph," T. Kaslow, The Decker Corp., Bala-Cynwyd, Pa.

BROADCASTING

Washington—May 22

"Automatic Data Processing in FCC Broadcast Application Handling," E. Davis, FCC.

CIRCUIT THEORY

Houston—May 9

"Determination of Passive Two-Part Network Function Using the Chain Matrix," F. Berman, Schlumberger Well Surveying Corp., Houston.

Los Angeles—April 18

"Applications of Semiconductors in High Quality Sound Systems," R. C. Heyser, Jet Propulsion Lab., Pasadena.

"Design Consideration of a Transistor Amplifier for High Fidelity Applications," R. V. Allee, Transistronics.

Philadelphia—May 26

"Adaptive Systems," D. F. Drenick, Bell Telephone Labs., Murray Hill, N. J.

Philadelphia—May 25

"Matched Filters, Fixed and Variable," Dr. R. Price, MIT Lincoln Lab.

Philadelphia—March 9

"Do It In Your Head—A Quick and Clean Approach to Filter Design," Dr. R. M. Lerner, MIT Lincoln Lab.

Philadelphia—December 14

"Signal-Space Concepts and Dirac's Notation," Dr. D. C. Lai, Brown University, Providence, R. I.

COMMUNICATIONS SYSTEMS

Los Angeles—April 25

"USAF Ground/Air/Ground Communications," L. J. McKesson, Hughes Aircraft Co., Los Angeles.

COMMUNICATIONS SYSTEMS VEHICULAR COMMUNICATIONS

Philadelphia—February 21

"A New Look for Air Force Communications," T. J. Heckelman, Philco Corp., Fort Washington, Pa.

(Continued on page 42A)

To Contractors and Subcontractors
on U. S. Government Projects

Western Electric offers high reliability semiconductors from Laureldale

- Western Electric's Laureldale, Pennsylvania, plant is now in its ninth year of producing semiconductor devices of ultra-high quality and reliability for government applications.
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- Mechanized production facilities and a comprehensive statistical quality control program assure uniformity and contribute to obtaining ultimate process capabilities.
- Reliability requirements specify 1000-hour elevated temperature life storage tests on all products shipped from Laureldale.

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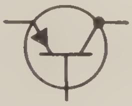
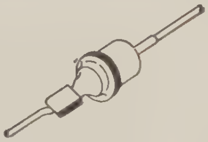
Diffused Base Germanium p-n-p Mesa Transistor. For ultra-high reliability in large computer systems. Rise times of 1-2 nanoseconds and storage and fall times of 3-4 nanoseconds obtainable.



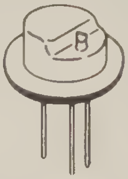
2N1195

Diffused Base Germanium p-n-p Mesa Transistor. Excellent for video or rf applications and as a non-saturating switch. 100 MC gain is ≥ 12 db. Alpha cut-off frequency is ~750 MC.



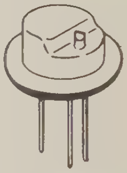
1N696

Diffused Silicon Junction Diode. Outstanding high-speed, low-capacity diode, with a maximum recovery time of 5 nanoseconds and a maximum capacitance of 4 picofarads.



2N1645

Diffused Base Germanium p-n-p Mesa Power Transistor. This transistor is designed to provide 1 watt of power output at 100 megacycles with an efficiency of 50%.



2N1072

Double Diffused Silicon n-p-n Mesa Transistor. This switches a current of 1 ampere with rise and fall times of 50 nanoseconds. The 2N1072 is an excellent core driver.

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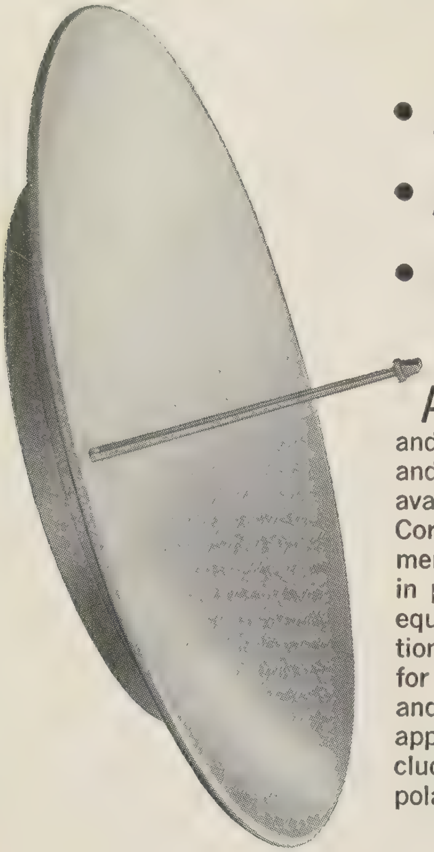

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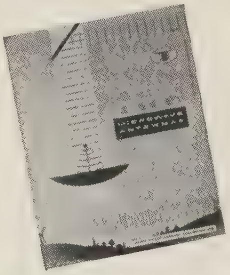

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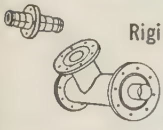
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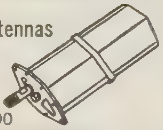
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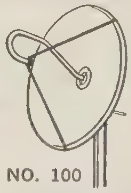
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Professional Group Meetings

(Continued from page 40A)

COMPONENT PARTS

Houston—May 9

"Trends and Application of Cylindrical Connectors," J. W. Busacker, Busacker Electronic Equipment Co., Houston.

Los Angeles—May 10

"Thin Magnetic Film Rod—A New Computer Switching Compound," B. Kaufman, National Cash Register, Los Angeles.

Omaha-Lincoln—May 13

"Tantalum Film Capacitors and Resistors," D. A. McLean, Bell Telephone Labs., Murray Hill, N. J.

Philadelphia—April 25

"Design for Development of an Ultra Reliability Resistor," L. Jacobson and J. Isken, IRC.

ELECTRON DEVICES

Washington, D. C.—May 10

"Recent Advances in Ultra-High Vacuum Techniques," Dr. L. Malter, Varian Associates, Palo Alto.

ELECTRONIC COMPUTERS

Boston—April 25

"Programming Languages and Debugging," S. G. Campbell, IBM.

Boston—March 7

"Easier Communication Between Man and Computer," M. P. Barnett, MIT; S. C. Plumb, IBM.

Boston—December 6

"Status and Prospects of Thin-Film Superconducting Circuits," N. H. Meyers, IBM.

Boston—December 6

"Status and Prospects of Thin Film Superconducting Circuits," N. H. Meyers, IBM.

Detroit—May 1

"Programming a Simple Adaptive Mechanism," F. H. Westervelt, University of Michigan, Ann Arbor.

Los Angeles—May 4

"Design for Reliability in the Minuteman Program," R. W. Cherney, North American Aviation, Downey, Calif.

Pittsburgh—May 15

"The Application of Digital Control Computers," R. W. Ferguson and R. O. Decker, Westinghouse Electric Corp., Pittsburgh.

(Continued on page 44A)

MIL/SPEC

GM-07-59-2617A

...Implemented by Capehart's INTERDICT GROUP

A veritable thicket of specifications has grown up around radio frequency interference measurements. Specification GM-07-59-2617A appears to be one of the thorniest. If you are having problems implementing this, or are experiencing any other difficulty connected with RFI, contact the INTERDICT Group from Capehart.

INTERDICT (for Interference Detection and Interdiction by Countermeasures Team) is a unique service. It began with the numerous field studies our engineers were carrying out. It grew into a series of mobile RFI measurement vans, an expanded force of engineers, a manual on RFI prediction by mathematical procedures, cognizance of all current military and industrial communications/electronic equipment, and formal organization into a team led by Dr. Joseph Vogelman, widely-known authority on RFI detection and elimination.

The engineers from INTERDICT are completely competent to aid in establishing: systems analysis, design limitations, criteria and test procedures. Follow through by INTERDICT engineers in the actual performance of these tests assures complete implementation of GM-07-59-2617A or any other relevant MIL Spec*. They have performed numerous systems and site analyses resulting in the prediction, detection and elimination of interference at such complex sites as Cape Canaveral and Vandenberg AFB, frequently before r-f interference occurred. They can offer you studies of this magnitude, or of very limited application, depending on your needs. INTERDICT possesses the men, the vans, the materiel, and the experience to analyze a complete proposed missile system, an individual site, or a single piece of installed equipment. The "package" can be tailored to the requirement.

The INTERDICT Group analyzes a proposed system for all r-f radiation sources, makes the necessary field measurements, predicts and determines the causes of interference, and recommends the proper remedial action. Should this latter require any equipment not commercially available, Capehart's quick-reaction engineering and model shop can provide what is needed very rapidly.

Capehart's INTERDICT offers the first world-wide packaged service to analyze and counteract radio frequency interference. It also provides for elimination of electromagnetic radiation hazards to personnel and materials such as squibs, ammo, fuel. All service is performed in compliance with applicable MIL Specifications such as that noted. To avail yourself of these unusual services, contact:

*Such as MIL-I-26600, I-6051, T-9107, S-10379, etc.

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Type	Max Q	Inductance Range
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TI-12	255	1MH to 30Hy
TI-1A	250	1MH to 30Hy
TI-1	210	5MH to 20Hy
TI-4	195	5MH to 5Hy
TI-5	130	5MH to 2Hy
TI-16	72	1MH to 2Hy

FREQUENCY RANGE: 10KC TO 50KC

TI-13	303	1MH to 500MH
TI-2	285	1MH to 500MH
TI-6	279	1MH to 400MH
TI-7	200	.500MH to 200MH
TI-17	110	.100MH to 100MH

FREQUENCY RANGE: 30KC TO 200KC

TI-18	115	.1MH to 100MH
TI-8	140	.1MH to 100MH
TI-10	185	1MH to 200MH
TI-9	175	1MH to 500MH
TI-19	100	.1MH to 5MH
TI-3	260	.1MH to 10MH
TI-3A	310	10MH to 100MH

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TI-21	205	.010MH to .150MH
TI-22	250	.010MH to .700MH
TI-23	210	.010MH to .500MH
TI-20	305	.050MH to 5MH

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MGA 2	Pri. 600 Split Sec. 4, 8, 16	Matching	90001	TF4RX16AJ002
MGA 3	Pri. 600 Split Sec. 135,000 C.T.	Input	90002	TF4RX10AJ001
MGA 4	Pri. 600 Split Sec. 600 Split	Matching	90003	TF4RX16AJ001
MGA 5	Pri. 7,600 Tap @ 4,800 Sec. 600 Split	Output	90004	TF4RX13AJ001
MGA 6	Pri. 7,600 Tap @ 4,800 Sec. 4, 8, 16	Output	90005	TF4RX13AJ002
MGA 7	Pri. 15,000 C.T. Sec. 600 Split	Output	90006	TF4RX13AJ003
MGA 8	Pri. 24,000 C.T. Sec. 600 Split	Output	90007	TF4RX13AJ004
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Professional Group Meetings

(Continued from page 42A)

Pittsburgh—April 24

"Design Considerations of Digital Control Computers," W. W. Ramage and J. S. Deliyannides, Westinghouse Electric Corp., Pittsburgh.

Pittsburgh—April 3

"Introductory Concepts of Digital Control," Dr. T. W. Sze, University of Pittsburgh.

Syracuse—April 27

"Cryogenic Memories," D. A. Donath, General Electric Co., Syracuse.

ELECTRONIC COMPUTERS RELIABILITY AND QUALITY CONTROL

Boston—Feburary 21

"Considerations in the Design of Control Computers," J. J. Eachus, and G. H. Bouman, EDP Div.

ENGINEERING MANAGEMENT

Philadelphia—May 23

"Engineering vs. Management," Dr. B. Tillett, Drexel Institute of Technology, Philadelphia.

Philadelphia—March 30

"The Use of Testing in Management Selection," S. H. Cleff, General Electric Co., Philadelphia.

Rome-Utica—April 25

"Management's Decision: Organization or Individual?" J. G. Nettleton, ITT Federal, Nutley, N. J.

"Management—Force or Persuasion," F. Oglee, General Electric Co., Croton, N. Y.

San Francisco—May 15

"Product Planning," B. Douglass, Marchant, Oakland, Calif.

"Engineering Organization," J. Kemper, Marchant, Oakland, Calif.

Tour of Marchant manufacturing facilities after talks.

ENGINEERING MANAGEMENT MILITARY ELECTRONICS RELIABILITY AND QUALITY CONTROL

Boston—April 20

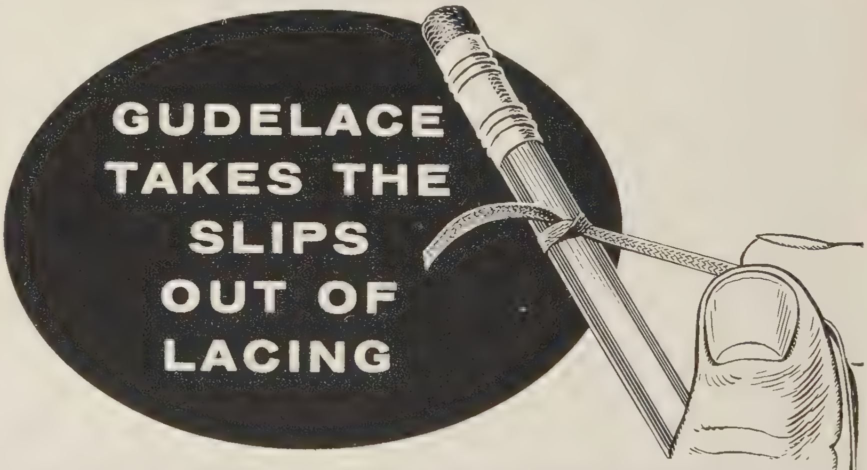
"How to Pay for Reliability," Panel of nine speakers, six from industry and three from military.

ENGINEERING WRITING AND SPEECH

Boston—May 16

"The Social and Economic Implica-

(Continued on page 46A)



Try this simple test. Tie a piece of Gudelace around a pencil in a half hitch and pull one end. Gudelace's flat, nonskid surface grips the pencil—no need for an extra finger to hold Gudelace in place while the knot is tied!

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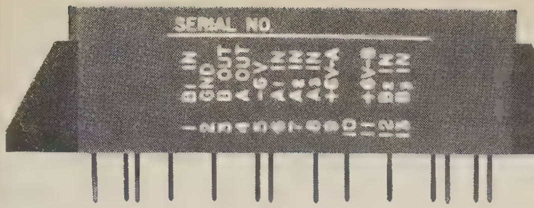

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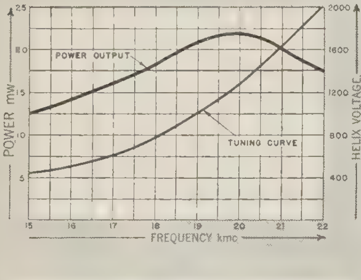

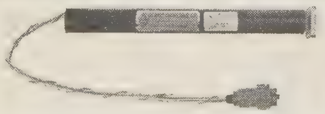

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Professional Group Meetings

(Continued from page 44A)

tions of Teaching Machines," G. Rath, Raytheon Co., Lexington, Mass.

San Francisco—May 16

"Technically Speaking," R. E. Garretson, Sound Products Co., South San Francisco, Calif.

Washington, D. C.—May 24

"Effective Communication," G. Thomas, Dept. of the Navy, Washington, D. C.

This was a joint meeting with the Society of Technical Writers and Publishers (STWP).

HUMAN FACTORS IN ELECTRONICS

Los Angeles—May 22

"Automatic Test Equipment," Moderator: Dr. G. Murphy, Douglas, Santa Monica.

"The Present State of Automatic Test Equipment," R. Gray, Nortronics.

"Some Claims for Automatic Test Equipment," J. A. Trapp, Hughes.

"Some Limitations of Automatic Test Equipment," S. I. Firstman, RAND.

"The Future of Automatic Test Equipment," H. R. LaPorte, Jr., Autonetics.

Los Angeles—March 28

Joint Meeting with Los Angeles Chapter, Human Factors Society.

"Automated Teaching—The Present?—The Future," J. F. Cogswell, Systems Development Corp.

"Controversies in the State of the Art," E. B. Fry, University of Southern California.

"Teaching Algebraic Concepts to Children," E. R. Keislar, UCLA.

"A Computer Based Laboratory for Automated School System," D. Bushnell, SDC.

"Predictions for the Future," J. D. Finn, University of Southern California.

Los Angeles—February 21

"Handling Problems of Hot Elements," J. F. Leirich, Atomics International.

INFORMATION THEORY

Los Angeles—April 19

"Interrupted Stochastic Control Processes," Dr. R. Bellman, RAND Corp., Santa Monica.

Los Angeles—November 22

"Optimum Statistical Methods," C. Leondes, M. Oaki and E. Stear, UCLA.

San Francisco—May 18

"Information Lossless Automata," D. Huffman, Mass. Inst. Tech.

(Continued on page 48A)

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- Q-max, an extremely low loss dielectric impregnating and coating composition, is formulated specifically for application to VHF and UHF components. It penetrates deeply, seals out moisture, provides a surface finish, imparts rigidity and promotes stability of the electrical constants of high frequency circuits. Its effect upon the "Q" of RF windings is practically negligible.
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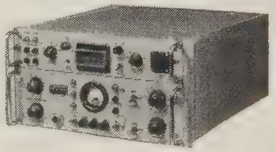

over commercial telephone circuits equipped with Rixon's fully transistorized, low error rate, highly reliable Sebit-24 Transmitter-Receiver.

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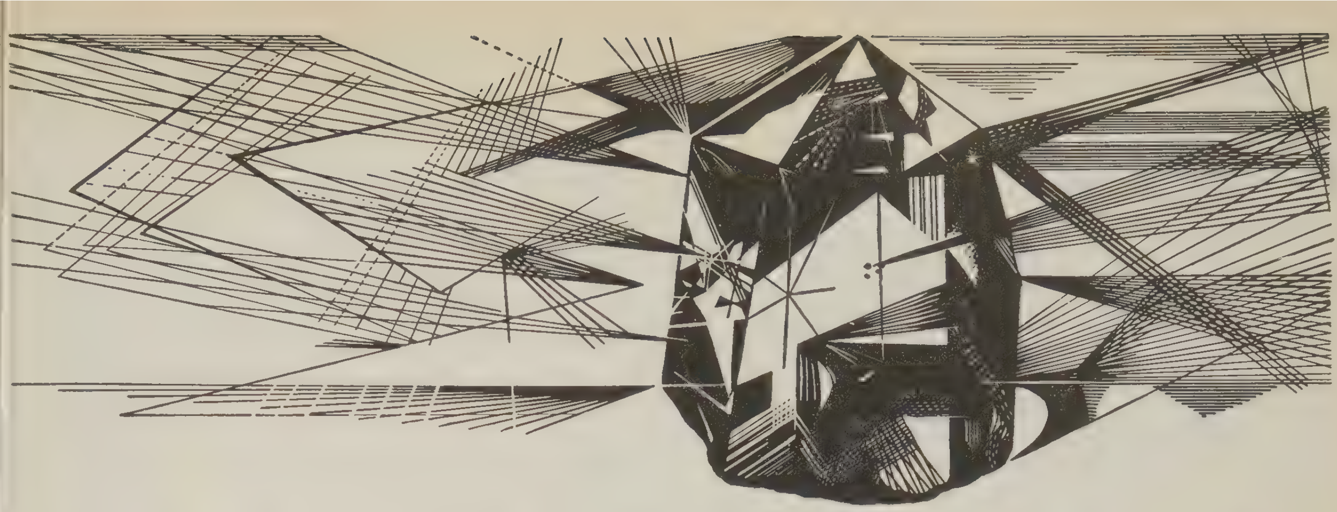


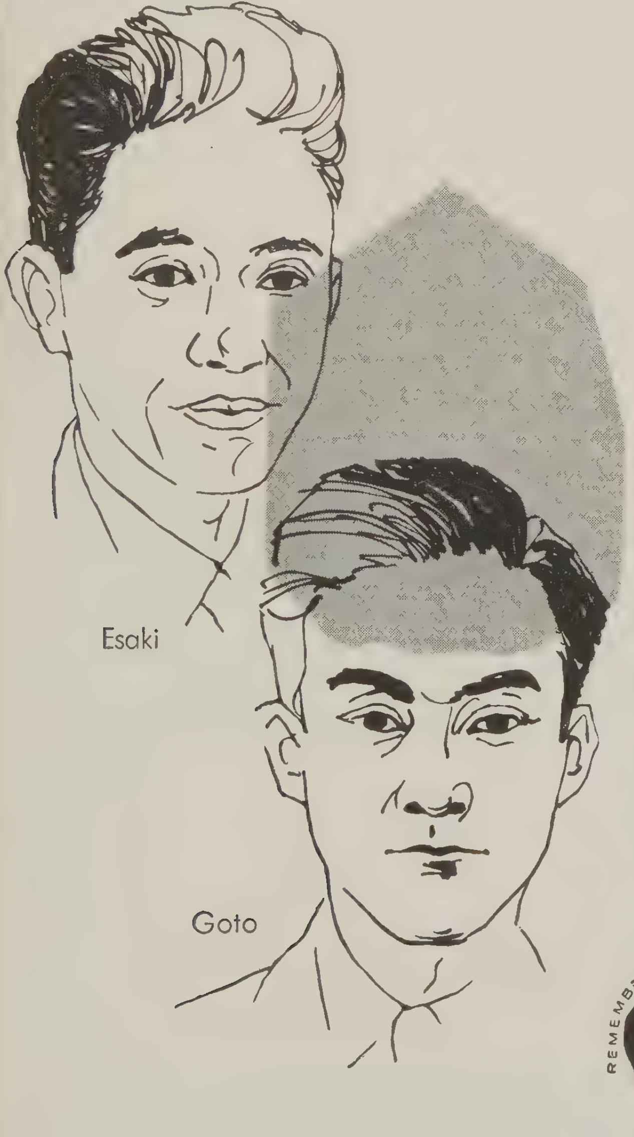
WHY CRYSTAL GAZE?

Some people look into crystals to tell the future, but one man looked into a crystal and *built* the future. His contribution: the use of crystals in radio.

Today the further use of crystals is revolutionising concepts in radio, hi-fi, and television, and the electric circuits being used in airplanes, computers, missiles. The scientists who study them are called solid-state physicists, and they include hundreds of members of the Institute of Radio Engineers, working in many lands, pooling their skill and knowledge for the betterment of man.

IRE is proud to honor two Japanese scientists for their outstanding contributions. To Leo Esaki, consultant at IBM Research Lab., Poughkeepsie, goes the 1961 *Morris N. Liebmann Award* for important contributions to the theory and technology of solid state devices; to Eiichi Goto, of Tokyo University, the *Browder J. Thompson Award* for a brilliant technical paper on "The Parametron, a Digital Computing Element."

The researches and findings of scientists like Mr. Esaki and Mr. Goto are published each month in *Proceedings of the IRE*, so that they become a part of our national pool of knowledge. Every electronics firm that advertises in *Proceedings* becomes a partner in this great enterprise.



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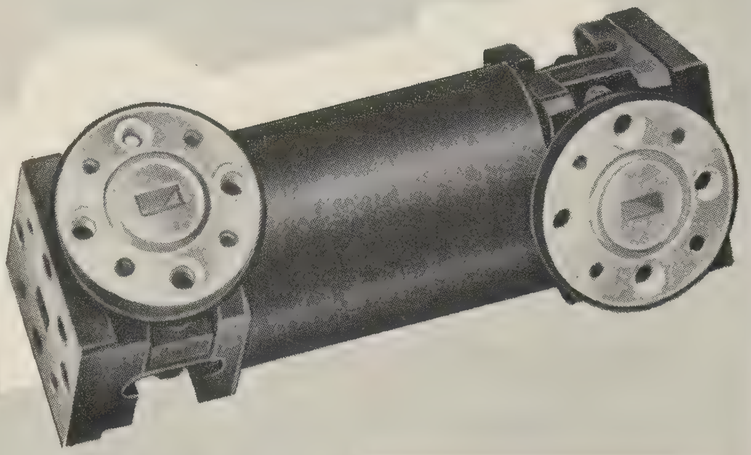

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In this frequency range FERROTEC has a complete line of:

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- ISOLATORS
- MODULATORS
- SWITCHES

Because of the low field necessary exceptionally high switching speeds can be attained. A sampling of typical units is tabulated below.

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MODEL	f_o (KMC)	BAND-WIDTH (MIN)
R-227LS	70	5%
T-153L*	70	3%
R-330L	67	6%
R-307LS	52.5	6%
R-300LS	35	6%
R-214LS	24	6%

**Junction Circulator*
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FERROTEC has the most complete line of ferrite devices in the industry — extending from 250MC to 75,000MC.

Contact your local sales representative or write to:

FERROTEC INC.

217 CALIFORNIA STREET • NEWTON 58, MASSACHUSETTS

Professional Group Meetings

(*Continued from page 46A*)

INSTRUMENTATION

Houston—May 9

"Gated Gamma Ray Spectral Logging," D. Britton, Humble Oil and Refining Co., Houston.

San Francisco—May 18

"Innovations in Test Instrumentation," C. Rasmussen, Lenkurt Electric Co., San Carlos, Calif.

MICROWAVE THEORY AND TECHNIQUES

Boston—April 27

"Frequency Multiplication and Division," Harmonic Study Group—R. Rivers, Moderator.

Buffalo-Niagara—October 28

"Millimicrosecond Pulse RF Techniques," Dr. P. R. McIsaac, Cornell University, Ithaca, N. Y.

Orlando—May 3

"Structures for High Power Traveling Wave Tubes," W. H. Yocom, Varian Associates, Palo Alto, Calif.

MILITARY ELECTRONICS

Boston—May 24

"Anti-Submarine Warfare and Task Group Bravo," Capt. G. Street, CDR W. F. Brennan, and Lt. P. R. Weatherby, USN.

Fort Huachuca—May 22

"Integrated Electronics," E. G. Witting, Deputy Asst. Secretary of Army for R & D.

Philadelphia—March 1

J. A. Keyes, Satellite Sales, GE: E. Fthenakis, Navigation and Control, GE; R. E. Roberts, Instrumentation and Communication, GE.

Summary of present and future programs being conducted by MSVD for the military and NASA. Various navigation and control projects at MSVD such as 3-axis stabilization of space vehicles and orbit control. Discussion of various present and future activities at MSVD in the field of instrumentation and communication for missiles and space vehicles, including sensors, telemetry transmitter, command system and basic communication systems. Also, display of various items of equipment relating to the presentations.

Rochester—May 4

"Computers—Artificial Intelligence—State-of-the-Art," D. Parkhill, General Dynamics/Electronics.

Rome-Utica—April 25

Mohawk Valley Management Seminar—Several papers and panel discussion.

(*Continued on page 50A*)

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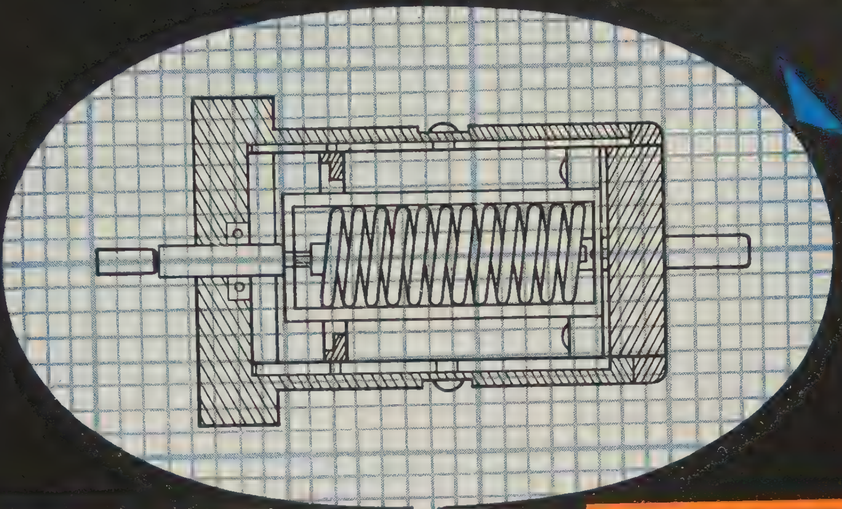

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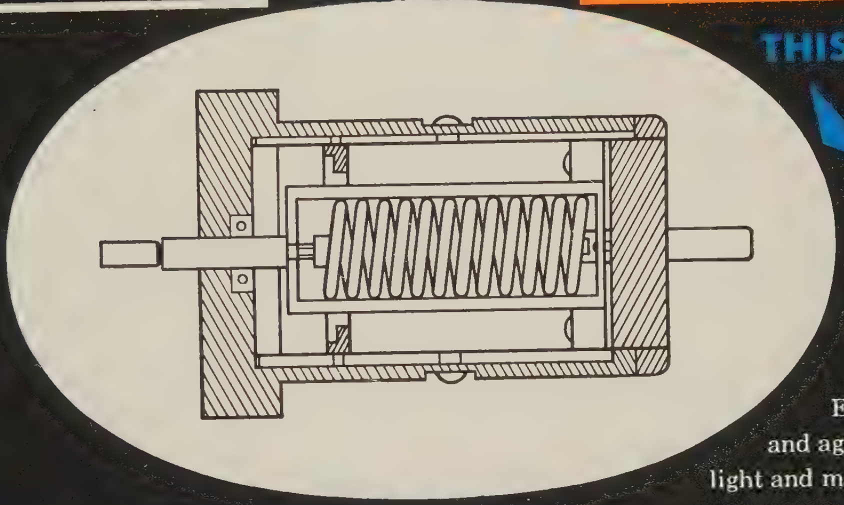

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Try Clearprint's perfect working surface with a 2H pencil – then with a pen. Lines are sharp and clear – Erase and draw the lines again and again. Now hold Clearprint to a light and make reproductions. No ghosts! Then test your present sheet.

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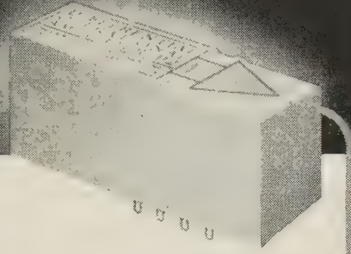

The all-new, all solid-state Philbrick P2 amplifier

NO TUBES, NO CHOPPERS, NOTHING BUT PERFORMANCE. An ingenious arrangement of all solid-state components endows this operational amplifier with the most remarkable and versatile characteristics. But let's let them speak for themselves. *Full differential input:* truly floating with respect to ground. *No common mode error. Low input current:* typically 10^{-11} amps. *Low noise:* typically under 10 microvolts in the dc to 1 kc range. *Sub millivolt long term stability:* less than 100 microvolts drift per day. *Cool running:* typically 330 milliwatt dissipation. *Wide band pass:* typically 75 kc as a unity gain follower. *High open loop gain:* typically 30,000. *Truly low cost:* **$210.**

Use the P2 for instrumentation, analog computation, and other applications requiring high reliability and accuracy. Discover its marvelous versatility and convenience. Add, integrate, scale, invert with it. Take advantage of its differential inputs to perform very high impedance voltage following (or amplification), precise current driving, and many other useful applications. The P2's output delivers 1 ma at ±10 volts. The cast aluminum housing fits right in your hand.

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Professional Group Meetings

(Continued from page 48A)

NUCLEAR SCIENCE

Albuquerque-Los Alamos—April 22

This meeting was the annual Section dinner meeting at Los Alamos.

"Selected Engineering-Physics Problems of a High-Current Multiple Rhumbatron Electron Accelerator," T. J. Boyd, Jr., Los Alamos Scientific Lab. and D. Venable, Los Alamos Scientific Lab.

E. C. Anderson, of the Los Alamos Scientific Lab., conducted the program for the ladies. This program consisted of a film and a tour of the Los Alamos whole body counter.

Los Angeles—May 23

"Radiation Effects on Computer and Inertial Guidance Systems Components," A. Kaufman and L. Gardner, Litton Systems, Woodland Hills, Calif.

Omaha-Lincoln—May 22

Symposium on Radiology.

PRODUCT ENGINEERING AND PRODUCTION

Boston—May 23

"Molular Sub-Miniature Packaging Techniques," G. W. Ruggiero, Control Equipment Corp., Needham, Mass.

Los Angeles—April 27

"Electrical Connections: Soldering," R. Michael, Claude Michael Agency, Inc., Glendale, Calif.

"Electrical Connections: Wire Wrapping," E. F. Julander, Gardner-Denver Co., Los Angeles.

"Electrical Connections: Welding," R. Hood, Wems, Inc., Hawthorne, Calif.

San Francisco—May 23

"Application of Electron Beams in Electronic Fabrication Processes," D. A. Vance, Lockheed, Palo Alto, Calif.

RADIO FREQUENCY INTERFERENCE

Fort Worth—April 18

The speaker of the evening was unable to attend due to business. However, the group was led in an open discussion of RFI problems by Dr. G. Harman, Fort Worth Section Chairman.

RELIABILITY AND QUALITY CONTROL

Boston—February 9

"Testing Methods and the Measurement of Reliability in Nuclear Weapons," L. J. Paddison, Sandia Corp.

Boston—December 8

"A General Approach to Reliability," A. Kocharian, Sylvania

"Tolerances," F. E. Dreste, Motorola.

(Continued on page 51A)

New Philbrick 6033 solid-state power supply

BALANCED OUTPUTS, COMPUTING GRADE. The 6033 is the latest addition in the distinguished line of Philbrick power supplies. It will energize at least 10 Philbrick P2 amplifiers and other transistorized electronic equipment. Like the P2, its remarkable characteristics speak for themselves. *Low internal impedance:* less than 2 milliohms. *Low noise and hum:* guaranteed less than 150 microvolts rms (0.001%). *Highly regulated outputs:* against load, less than 300 microvolts; against line, less than 200 microvolts. *Low long term drift:* typically 0.1%. *Short transient recovery time:* no load to full load, less than 1 millisecond. *Unique short circuit overload protection:* inherent in the 6033's design with no extra circuitry to deteriorate performance. *Truly low cost:* about half that of supplies with comparable performance: **$285.**

Operates from 115 volt, 50–400 cycles, providing up to 150 ma at plus AND minus 15 volts, slaved to a common reference. Conveniently packaged, cool running, and highly reliable. Available as bench model or modular plug-in. Bench model dimensions: 3½" h x 5½" w x 7½" d. Also available with 300 ma output.

Complete facts are waiting for you. Please write:

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Professional Group Meetings

(Continued from page 50A)

Fort Worth—May 16

"Reliability in Production," K. D. Davidson, Texas Instruments, Dallas.

Fort Worth—May 9

"Designing for Reliability," J. E. Hasty, Texas Instruments, Dallas.

Fort Worth—May 2

"Fundamental Statistics in Reliability," C. A. Hardy, General Dynamics, Fort Worth.

Fort Worth—April 25

"Reliability Concepts," F. Quirino, General Dynamics, Fort Worth.

Los Angeles—May 15

"AGREE Task Group 3 Test," D. Andree, RCA, Van Nuys.

"Transformer Testing," W. X. Lamb, Bendix-Pacific, North Hollywood, Calif.

"A Practical Example of Testing for Reliability," L. Arndt, Hoffman Labs.

Philadelphia—May 16

"Failure Modes and Mechanisms in Electronic Parts," W. Cole, Lansdale Tube Co., Div. of Philco.

"Failure Analysis," S. Dodge and R. Lull, Burroughs Corp., Paoli.

Philadelphia—April 19

"Predicting Drift Reliability of Digital Circuits," J. E. Anderson, IBM, Owego.

"Design Reviews," A. L. Consalvi, RCA, Moorestown, N. J.

SPACE ELECTRONICS AND TELEMETRY

Albuquerque—March 21

"Project Mercury Telemetry and Receiving Station," H. O. Jeske, Sandia Corp., Albuquerque, N. M.

San Francisco—March 24

"Introduction to Phase-Lock Loops," C. S. Weaver, Philco, Palo Alto.

VEHICULAR COMMUNICATIONS

Detroit—May 24

"Improving Receiver Design through the use of High Frequency Filtering," S. Meyer, Hammarlund Mfg. Co., Inc., New York, N. Y.

Los Angeles—January 19

"'Squeeze Play' or 15-kc Separation of Mobile Radio Channels," J. A. McCormick, General Electric Co.

"The Helipole Antenna," J. Montgomery, Andrew Calif. Corp., Claremont, Calif.

Philadelphia—March 28

"Public Air Ground Radiotelephone System," M. C. Fruehauf, American Telephone & Telegraph Co., Philadelphia.

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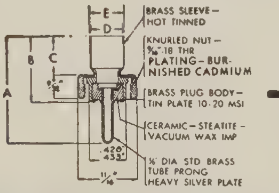
PHOTO-CELL WORK
MICROPHONE CONNECTIONS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9/32"
BRASS SLEEVE—HOT TINNED
KNURLED NUT—9/16"-18 THR
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BRASS PLUG BODY—TIN PLATE 10-20 MSI
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JONES
SHIELDED TYPE
PLUGS & SOCKETS

LOW LOSS PLUGS AND SOCKETS FOR HIGH FREQUENCY CONNECTIONS

For quality construction thruout, and fine finish, see diagram above.

101 Series furnished with ¼", .290", 5/16", ⅜", or ½" ferrule for cable entrance. Knurled nut securely fastens unit together. Plugs have ceramic insulation; sockets bakelite. Assembly meets Navy specifications.

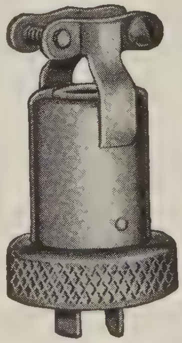
202 Series Phosphor bronze knife-switch type socket contacts engage both sides of flat plug contacts—double contact area. Plugs and sockets have molded bakelite insulation.

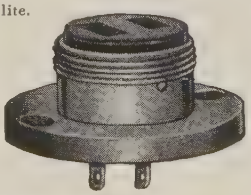
For full details and engineering data ask for Jones Catalog No. 22.

JONES MEANS *PROVEN* QUALITY

P-101-¼

S-101


P-202-CCT


S-202-B

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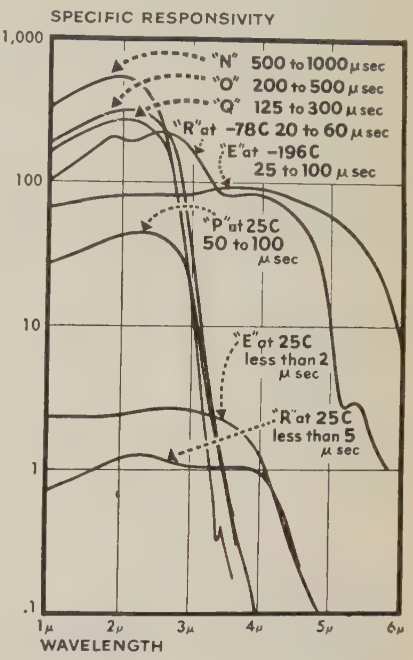
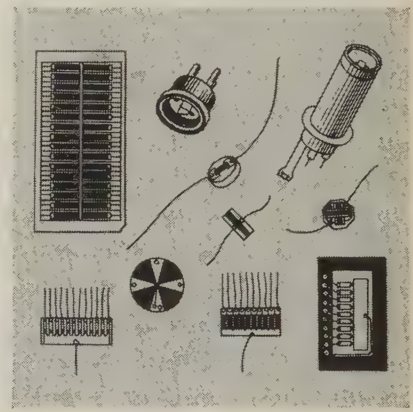
KODAK EKTRON DETECTORS
-for the 1μ to 6μ infrared



a wide-open choice in spectral responsivity and time constant



a wide-open choice of physical forms—large, small, complex shapes, multiple arrays, "immersed," Dewar-housed—ingenuity is the only limit, almost

For more precise explanations and a price list of off-the-shelf Kodak Ektron Detectors (or to see if we can build a complete infrared system for you), write—

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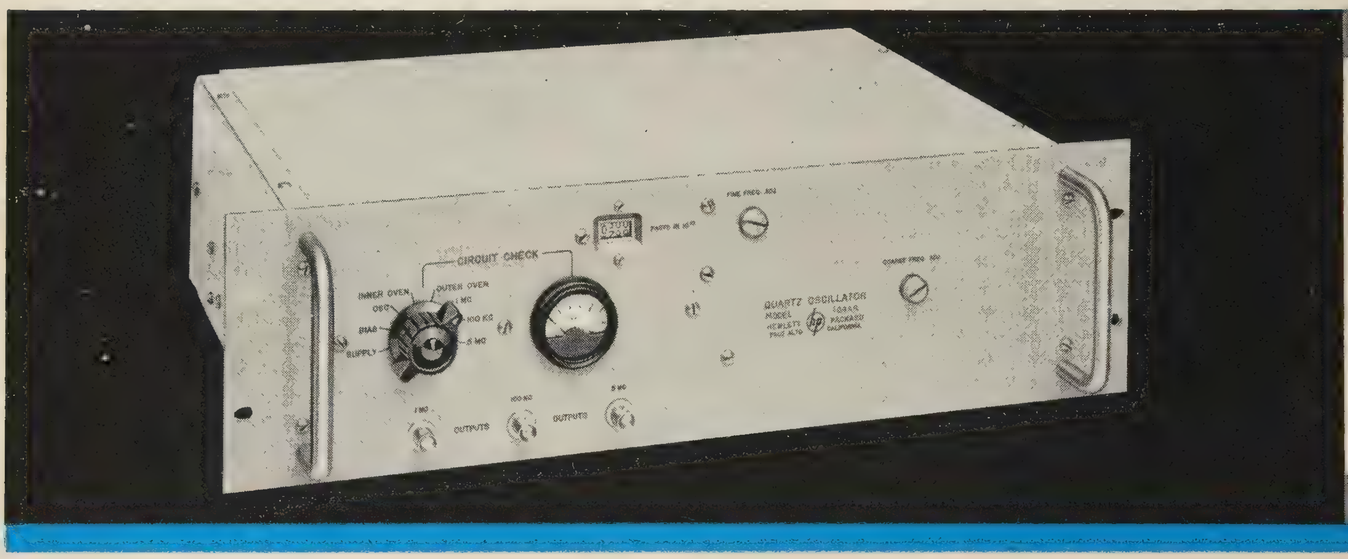
NOW! NEW STANDARDS OF FREQUENCY STABILITY, SPECTRAL PURITY WITH NEW hp 104AR QUARTZ OSCILLATOR

Long term stability: 5 parts in 10^{10}/day

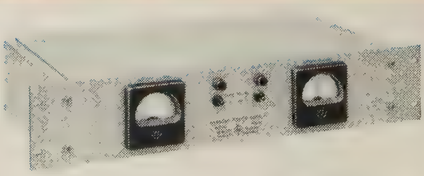
Typical short term stability*: 1 part in 10^{10}

Spectral purity: 2 cps typical bandwidth at X-Band

*averaged over one second intervals
and under reasonably constant
environmental conditions.


CIRCUIT CHECK
INNER OVEN
OUTER OVEN
OSC
BIAS
SUPPLY
1 MC
100 KC
5 MC
PARTS IN 10^10
FINE FREQ. ADJ
COARSE FREQ. ADJ
QUARTZ OSCILLATOR
MODEL 104AR
HEWLETT PACKARD
PALO ALTO CALIFORNIA
1 MC
OUTPUTS
100 KC
OUTPUTS
5 MC

Precision instruments for "Building Block" frequency/time standard systems allow comparison with HF, VLF standard broadcasts.



hp 724BR/725AR Standby Power Supplies

These standby power supplies are completely automatic, assure continued operation of frequency and time standard systems in the event of ac line power failure. Standby batteries floating across supply outputs, instantly assume load, without switching, in case of ac failure. Battery recharged automatically after ac line power is restored. hp 724BR battery operates 103/104AR, 113BR up to 48 hours. hp 725AR battery operates 103/104AR, 113BR at least 6 hours. hp 724BR, 75 lbs., $850.; hp 725AR, 20 lbs., $625.

Data subject to change without notice. Prices f.o.b. factory

The accuracy, stability and spectral purity you need for communication, navigation, missile guidance, satellite tracking and other advanced frequency/time standard applications are yours now with the new hp 104AR Quartz Oscillator.

Model 104AR provides a 5 MC output of extreme spectral purity that retains the stability of the 1 MC oscillator. Spectra only a few cycles wide may be obtained in the X-Band region by multiplication of the 5 MC output. Model 104AR also provides 1 MC and 100 KC sinusoidal output signals, plus a separate 100 KC output for driving hp 113BR Frequency Divider and Clock in frequency and time comparison measurements and time signal generation. The 113BR, which permits greater absolute accuracy from frequency or time standards and is suitable for HF or VLF comparisons, is described below.

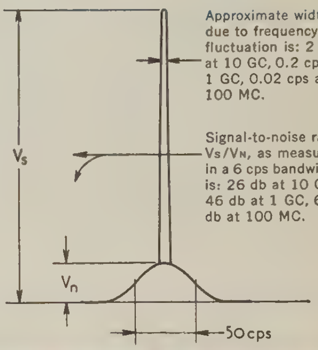
Continuous operation of hp 104AR and hp 113BR is assured with hp 724BR/725AR Standby Power Supplies (also described below). Models 724BR/725AR provide power for the oscillator and frequency divider, and incorporate batteries to insure operation of the system in case of ac power failure. These instruments, plus a comparison device and a receiver, provide a compact, lightweight, rugged, stable and accurate primary frequency and time standard system.

The new hp 104AR Quartz Oscillator, which is completely transistorized, employs a proportionally-controlled double oven which houses the crystal and all critical frequency-determining elements. Crystal dissipation level is kept constant at less than 1/4 μw by AGC action. Frequency changes due to variations in supply voltage and load impedance are virtually eliminated as a result of internal voltage regulation and excellent buffering.

SPECIFICATIONS, hp 104AR

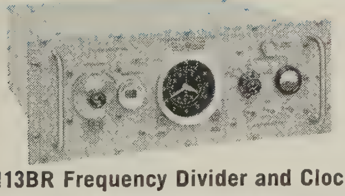
Overall Stability:	Long term: 5 parts in 10^{10}/day. Short term: Better than 5 parts in 10^{10} averaged over 1 sec. intervals. (Includes effects of temperature, supply voltage and load impedance.)
Output Frequencies:	5 MC, 1 MC, 100 KC, 1 v rms into 50 ohms, 100 KC for driving hp 113AR/BR.
Harmonic Distortion:	At least 40 db below rated output.
Non-harmonically Related Output:	At least 80 below rated output.
Output Terminals:	5 MC, 1 MC, 100 KC, front and rear BNC connectors.
Frequency Adjustments:	Coarse: Screwdriver adjustment with range of approx 1 part in 10^6. Fine: Front panel screwdriver control with range of approx. 600 parts in 10^{10}. Digital indicator calibrated directly in parts in 10^{10}.
Monitor Meter:	Ruggedized front-panel meter and associated selector switch monitors the SUPPLY voltage, BIAS, OSC current, INNER OVEN current, OUTER OVEN current, 1 MC output, 100 KC output.
Temperature Range:	0 to 50° C.
Size:	19″ x 5¼″ x 14″ deep behind panel. Approx. 20 lbs.
Price:	hp 104AR, $3,250.00

Typical Spectral Purity, hp 104AR



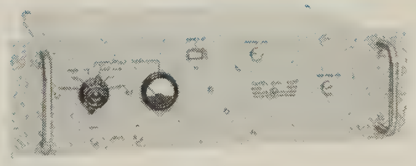
Approximate width due to frequency fluctuation is: 2 cps at 10 GC, 0.2 cps at 1 GC, 0.02 cps at 100 MC.

Signal-to-noise ratio, V_S/V_N, as measured in a 6 cps bandwidth, is: 26 db at 10 GC, 46 db at 1 GC, 66 db at 100 MC.



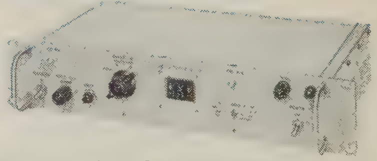
hp 113BR Frequency Divider and Clock

This improved hp instrument uses a directly calibrated precision resolver as a time reference control, offers unique jitter-free optical gating system. Clock is fail-safe, incorporates regenerative non-self-starting dividers insuring neither gain nor loss of time with respect to driving oscillator. Time reference is continuously adjustable, directly calibrated in millisecond and 10 microsecond increments. Manual-start clock, 24 hour dial, minute hand adjustable in 1 minute steps, second hand continuously adjustable. hp 113BR, $2,750.



hp 103AR Quartz Oscillator

Offers excellent spectral purity, and same long-term and short-term outputs as Model 104AR. Outputs same as 104AR except does not include 5 MC output. Completely transistorized, rugged, withstands severe environmental conditions. Otherwise electrically similar to 104AR. hp 103AR, $2,500.



hp 114BR Time Comparator

An auxiliary unit used in conjunction with the hp 113BR, the hp 114BR allows time comparison without affecting clock outputs, provides additional speed and flexibility in making time comparisons between stable oscillators and standard time signal transmission. Range, time intervals 0-999 milliseconds between ticks from hp 113BR and standard time signal station, can be used with VLF or HF time signals. hp 114BR, $1,200.

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Palo Alto, California, U.S.A.
DAvenport 6-7000

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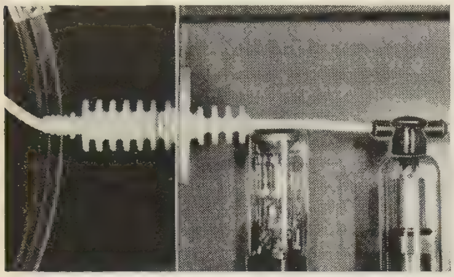
Sales representatives in all principal areas

7060

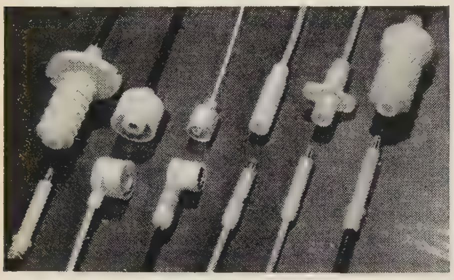
high voltage connector problems?



ALDEN

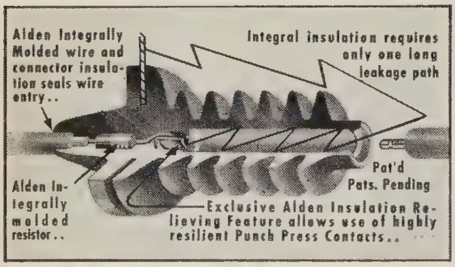
solves them by return mail

Alden makes high voltage connectors that are more reliable . . . simpler . . . and less expensive. Connectors you can trust absolutely to tame arc-over and corona problems at voltages as high as 30 KDVC.



A few of the many Alden IMI High Voltage Connectors and tube caps available for solving your problems.

It's done through Alden's exclusive IMI (Integral Molded Insulation) technique. With this unique method, we can mold Kel-F, Polyethylene, or Nylon insulation in a single hot shot directly around leads, contacts, and any special circuit components like chokes, resistors, or corona shells.


Alden Integrally Molded wire and connector insulation seals wire entry..
Integral insulation requires only one long leakage path
Pat'd Pats. Pending
Alden Integrally molded resistor..
Exclusive Alden Insulation Relieving Feature allows use of highly resilient Punch Press Contacts..

This one shot technique saves production costs. These savings are passed on to you. And it actually adds reliability.

Let us prove it. Let us send you complete information by return mail. Better still, send us a sketch. Tell us what you want to connect. Lay out lead lengths, give voltage and current, environmental conditions. We'll send you a sample connector assembly or a proposal specifically tailored to your needs. Just write:

ALDEN
PRODUCTS COMPANY
117 N. Main Street, Brockton, Mass.
See us at WESCON booth 4219

IRE People

Eugene R. Kulka (M'58) has been elected to the Board of Directors of Gold Seal Products Corporation. Stockholders of the company at the annual meeting also voted to change the name to Kulka Electronics Corporation. He becomes the eleventh member of the Board.

Mr. Kulka, inventor, pioneer and leader in electric lighting, electrical displays and electronics for forty years, will continue as president to Kulka Electric Corporation, subsidiary of the parent firm. He holds many patents in the electrical field.

He is a member of many scientific and engineering societies, including the American Association for the Advancement of Science, American Institute of Electrical Engineers, Federation of American Scientists, New York Academy of Sciences, Society of American Military Engineers, Illuminating Engineers Society, Army Ordnance Association, National Electrical Manufacturers Association, Society of Plastic Engineers and American Association of Engineers.

He is a founder member of Technion, the Israel Institute of Technology, Chairman of the Civic Affairs Committee of Mount Vernon, and Electrical Industry Chairman of the United Jewish Appeal of Greater New York.

❖

A. J. Lovenstein

The appointment of **Allen J. Lovenstein** (SM'57) as Manager of the ADVENT satellite communications program at the Waltham Laboratories of Sylvania Electronic Systems, a division of Sylvania Electric Products Inc., has been announced.

The Waltham program is being conducted under the direction of the U. S. Army ADVENT Management Agency and the technical guidance of the U. S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.

Project ADVENT embraces work leading to a determination of the feasibility of a world-wide communications network that will operate through utilization of "stationary" satellites. Sylvania is responsible for development, fabrication and installation of all operations facilities for the two ADVENT satellite tracking and terminal communications stations being constructed at Fort Dix, N.J., and Camp Roberts, Calif.

The company project includes design and fabrication of towers and superstructures that will aim gigantic 60-foot parabolic reflector antennas at each station with their complex multiple-feed systems to track distant satellites within an accuracy never before attained.

Mr. Lovenstein previously served as manager of market development and analysis at the Waltham Laboratories. Prior to joining Sylvania, he was project engineer for the Crosley Division of Avco Corporation in charge of development of a steerable array communication system.

He served with the U. S. Army Signal Corps during World War II as a member of an American liaison team with the British and Nationalist Chinese armies in Burma. In 1947, he joined the Signal Corps Laboratories at Fort Monmouth, where he served until 1956 as project engineer on a series of task forces directly related to the defense effort.

He received the Bachelor's degree in electrical engineering from City College of New York. He is a member of the Armed Forces Communications and Electronics Association, the Electronic Industries Association, American Marketing Association and American Rocket Society.

❖

M. H. Mehr

Morton H. Mehr (A'51–M'56) is Vice President and General Manager of the newly-formed Measurement Systems, Inc., South Norwalk, Conn. The Company will develop and manufacture electro-optical and infrared equipment.

He was formerly a Group Leader in the Advanced Development Section of the Perkin-Elmer Corporation, Norwalk, Conn., where he was project engineer on an infrared surveillance system and directed a portion of the development and field installation of several large telescopic camera systems. He was previously with Stelma, Inc., Stamford, Conn., where he was a project engineer.

Mr. Mehr received the B.E. degree in electrical engineering from Yale University, New Haven, Conn., in 1950. He is a member of the American Institute of Electrical Engineers and the Society of Motion Picture and Television Engineers.

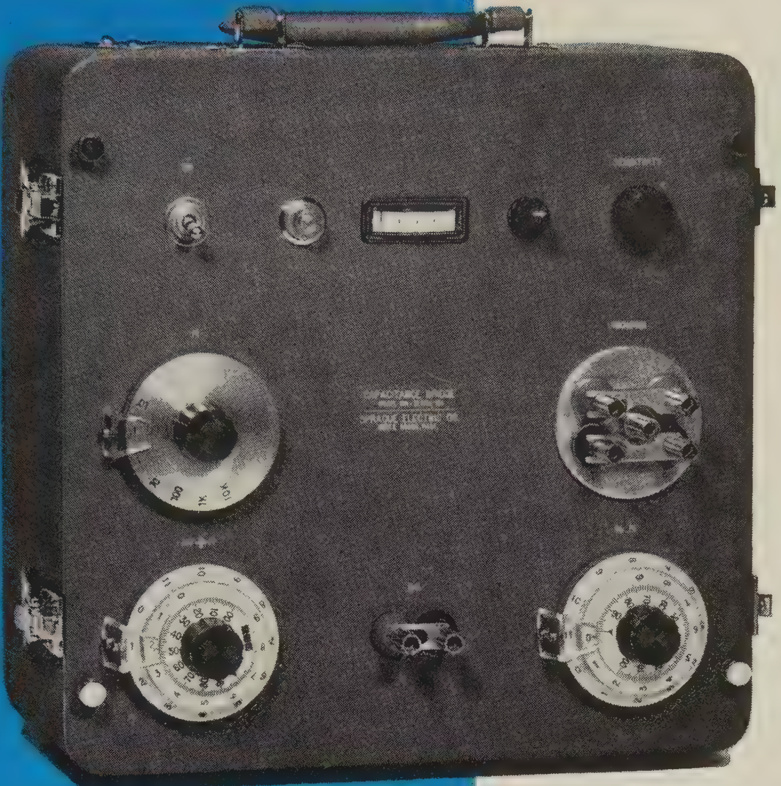
❖

Vernon G. Price (M'52) has joined the senior staff of Electromagnetic Technology Corporation, Palo Alto, Calif., as Manager of Components, according to a recent announcement.

He has been assigned responsibility for

(Continued on page 56A)

Now! For the first time...



TEST ELECTROLYTIC CAPACITORS

Safely... Accurately... Simply!

SPECIFICATIONS

Capacitance
Range: 0 to 120,000μF at 120 cps
Accuracy: ±(1% of reading* +10μμF)
Sensitivity: ±(0.1% of reading +10μμF)
Dissipation Factor
Range: 0 to 120% at 120 cps
Accuracy: ±(2% of reading +0.1% DF)
Sensitivity: ±(0.2% of reading +0.05% DF)
Maximum Voltage to Unknown
A-C: 0.5v RMS at 120 cps
D-C: 0-600v (with optional power supply)
Null Detection
Built-in Galvanometer to
Indicate Bridge Balance
Power Input
105-125v, 60 cps, 25w
Case
Sturdy Aluminum Cabinet with
Blue Textured Finish, Grey Panel
Dimensions
12" Wide x 12" High x 6" Deep

**Note: Five other models, with variations in power inputs and test frequencies, are also available.*

■ The Sprague Model 1W1 Capacitance Bridge introduces a new concept in bridge design. Built by capacitor engineers for capacitor users, it incorporates the best features of bridges used for many years in Sprague laboratories and production facilities.

■ Using a line-driven oscillator with but two active elements (diodes), the bridge has a transistorized detector whose sensitivity increases as the balance point is approached. It has provision for 2-terminal, 3-terminal, and 4-terminal measurements, which are essential for accurate measurement of capacitors with low, medium, and high capacitance values, respectively.

■ The Model 1W1 Capacitance Bridge will not cause degradation or failure in capacitors during test, as is the case in many conventional bridges and test circuits. The 120 cycle a-c voltage, applied to capacitors under test from a built-in source, never exceeds 0.5 volt! It is usually unnecessary to apply d-c polarizing voltage to electrolytic capacitors because of this safe, low voltage.

For complete technical data on this precision instrument, write for Engineering Bulletin 90,010 to Technical Literature Section, Sprague Electric Company, 235 Marshall Street, North Adams, Massachusetts.

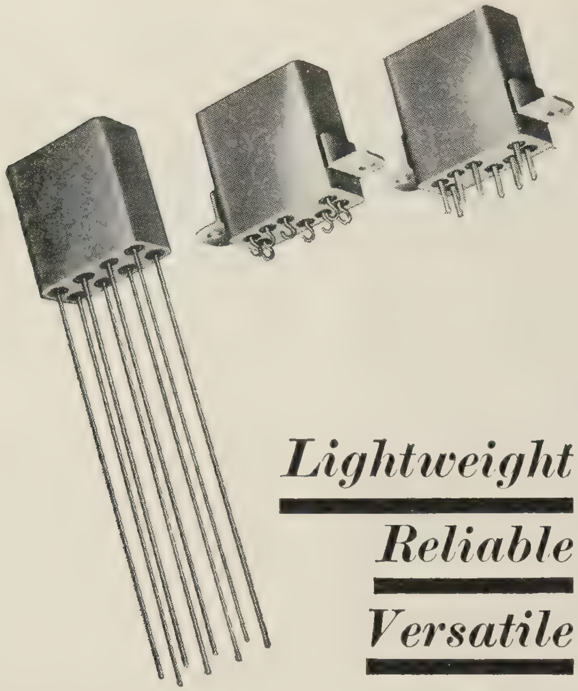
ELECTRONIC PRODUCTS by SPRAGUE

CAPACITORS
RESISTORS
MAGNETIC COMPONENTS
TRANSISTORS
INTERFERENCE FILTERS
PULSE TRANSFORMERS
PIEZOELECTRIC CERAMICS
PULSE-FORMING NETWORKS
HIGH TEMPERATURE MAGNET WIRE
CERAMIC-BASE PRINTED NETWORKS
PACKAGED COMPONENT ASSEMBLIES
FUNCTIONAL DIGITAL CIRCUITS

SPRAGUE®
THE MARK OF RELIABILITY

'Sprague' and '②' are registered trademarks of the Sprague Electric Co.

MICRO-MINIATURE RELAYS / STYLE 6



Lightweight

Reliable

Versatile

. . . for low-level and power load switching

Style 6 Micro-miniature Relays are lightweight, crystal can style relays designed to give superior performance in miniaturized assemblies. The basic design is particularly well suited for mass production of high quality relays that are as versatile as they are reliable.

Style 6 Relays operate at coil power levels below most larger current-sensitive relays in their general class, yet easily switch load currents of 2 amps resistive and higher at 26.5 VDC or 115 VAC. Suitable for operation at ambient temperatures to 125°C; withstand 50 G Shock and 20 G Vibration to 2000 cycles. Contact arrangements to DPDT. Terminals and mountings can be provided to meet most requirements.

Meet requirements of the following specifications and drawings: MIL-R-5757D Type RY4NA3B3L01, MS24250-6, and MIL-R-25018 Class B, Type II, Grade 3. Suggested applications include missiles, computers and control systems.

See us at the WESCON Show Booth 2806

For Additional Information, contact:

PRICE ELECTRIC CORPORATION

300 E. Church Street • Frederick, Maryland
MOnument 3-5141 • TWX: Fred 565-U

(Continued from page 54A)

guiding the corporation's activities in the area of radio frequency component development. Initial activities will center on high power microwave filters, measurement devices and techniques for the control of radio frequency interference. He is nationally recognized as an authority in his field, having made many contributions to the technology of radio frequency environment control. He recently resigned from the General Electric Company, Traveling Wave Tube Product Section, Palo Alto, Calif., where he has been employed for the past six years.

He served in the United States Navy as an Electronics Technician and subsequently was employed at the Naval Electronics Laboratory, San Diego, Calif., in the development of underwater sound technology.

A native of Utah, Mr. Price holds the Bachelor's and Master's degrees from the University of Utah, Salt Lake City

❖

Kenneth M. Miller (SM'54), formerly Vice President of Motorola Aviation Electronics, has been named Vice President and General Manager of Daystrom-Pacific, Los Angeles, Calif., a division of Daystrom, Inc.

Widely known for his work in the airborne instrument, automatic flight control, communication and navigation fields, Mr. Miller previously served as General Manager and earlier as Chief Engineer of the Lear Cal division of Lear, Inc.

K. M. Miller

❖

The appointment of **Dr. Harold R. Raemer** (M'59) as a physics specialist at the Applied Research Laboratory of Sylvania Electric Products Inc., has been announced.

In his new capacity, he will be engaged in a theoretical research program seeking new knowledge on the propagation of very low frequency radio waves. He will also participate in a project involving microwave transmission through ionized gases.

Co-author of several technical reports and articles, Dr. Raemer and H. Hodara, Head of Space Communications, Hallicrafters Company, Chicago, Ill., delivered a paper entitled "Space Communication Problems During Re-entry" before many of the world's leading space scientists at the 11th International Astronautics Congress in Stockholm, Sweden, in August, 1960. Another co-author of the paper was Dr. G. I. Cohn, Professor of Electrical

(Continued on page 60A)

measure / analyze, 100 cps - 600 kc signals quickly, easily, with one compact instrument

PANORAMIC'S

SB-15a

ULTRASONIC SPECTRUM ANALYZER

Panoramic's advanced Model SB-15a automatically and repetitively scans spectrum segments from 1 kc to 200 kc wide through the entire range (100 cps to 600 kc) . . . plots frequency and amplitude along the calibrated X and Y axes of a long persistence CRT, or on a 12 x 4½" chart (optional RC-3a/15). Sweep rates are adjustable from 1 to 60 cps.

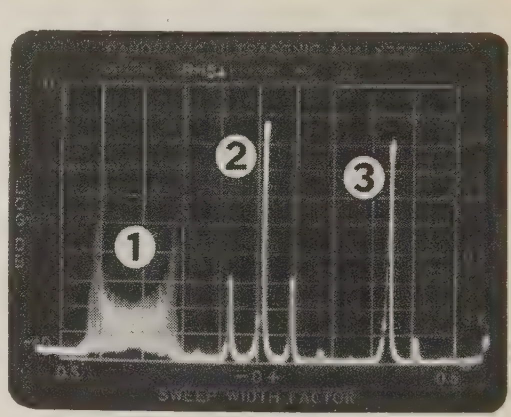
Adjustable resolution enables selection and detailed examination of signals as close as 100 cps. Self-checking internal frequency markers every 10 kc. Also internal amplitude reference • Only 8¾" high, the SB-15a is completely self-contained, needs no external power supply or regulator.

PANORAMIC PRESENTATION MEANS

● quick signal location, minimum chance of missing weak signals or holes in spectrum ● faster measurements—no tedious point-by-point plots ● reliable spotting of low level discrete signals in noise ● positive identification and dynamic analysis of all types of modulation

ALL THESE APPLICATIONS . . .

● Noise, vibration, harmonic analysis ● Filter & transmission line checks ● Telemetry analysis ● Communication System Monitoring . . . and more ● Power Spectral Density Analysis (with Model PDA-1 Analyzer) ● Frequency Response Plotting (with Model G-15 Sweep Generator)



Lab setup shows SB-15a versatility. (1) FM display measures dynamic deviation. (2) & (3) are AM and SSB signals, respectively, with sine wave modulation.

SUMMARY OF SPECIFICATIONS

Frequency Range: 100 cps to 600 kc.

Sweepwidth: Variable, calibrated from 1 kc to 200 kc.

Center Frequency: Variable, calibrated from 0 to 500 kc.

Markers: Crystal controlled, 10 kc and 100 kc plus harmonics.

IF Bandwidth: Variable, 100 cps to 4 kc.

Sweep Rate: Variable, 1 cps to 60 cps.

Amplitude Scales: Linear, 40 db log (extendable to 60 db) and 2.5 db expanded.

Sensitivity: 200 µv to 200 v full scale deflection.

Accuracy: ±0.5 db.

Input Impedance: 55 k ohms.

Write now for specifications, other applications of PANORAMIC's Model SB-15a. Get on our regular mailing list for THE PANORAMIC ANALYZER, featuring application data.

**SEE US
at
WESCON
Booths
3202-
3204**

dependable CERTIFIED SPECIFICATIONS for accurate data

the pioneer is the leader

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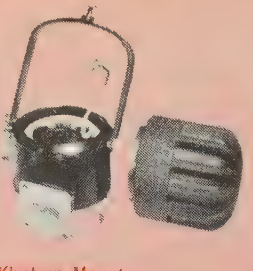
ULTRAMICROWAVE®

Directional Coupler

Precision Attenuator


Klystron Mount

Standard Gain Horn

Crystal Mount

Size Designation Frequency Band in KMC Waveguide Nomenclature	DBW 90-140 RG-138/U		DBA 60-90 RG-99/U		DBB 50-75 RG 98/U		DBC 33-50 RG-97/U		DBD 26 5-40 RG 96/U		DBE 18-26 5 RG 53/U		DBF 12 4-18 RG-91/U		DBG 8.2-12.4 RG-52/U		DBH 7 05-10 0 RG-51/U		DBJ 5 85-8 2 RG-50/U		·DBK 3 95 5 85 RG-49/U		DBL 2 6-3.95 RG-48/U	
	Cat No	*Price*	Cat No	*Price*	Cat No	*Price*	Cat No	*Price*	Cat No	*Price*	Cat No	*Price*	Cat No.	*Price*	Cat No.	*Price*	Cat No	*Price*	Cat No.	*Price*	Cat No	*Price*	Cat No.	*Price*
Tube Mounts																								
Klystron Tube Mount											DBE 111	*$42*			DBG-111 1	*$215*	DBH-111-1	*$225*	DBJ-111-1	*$260*	DBK-111-1	*$270*	DBL-111 1	*$285*
Noise Tube Mount with Tube							DBC-140-T	*$325*	DBD-140-T	*$278*	DBE-140-T	*$225*	DBF-140-T	*$230*	DBG-140-T	*$200*	DBH-140-T	*$210*	DBJ-140-T	*$235*	DBK-140-T	*$265*	DBL-140-T	*$300*
Transmission Line Components																								
Adaptors, Choke to Cover									DBD-010	*$30*	DBE 010	*$26*	DBF-010	*$26*	DBG-010	*$20*	DBH-010	*$27*	DBJ-010	*$37*	DBK 010	*$46*	DBL 010	*$73*
Tapered Transitions	DBWB-018	*$125*	DBAB-018	*$100*	DBBC-018	*$90*	DBCD-018	*$90*	DBDE-018	*$85*	DBEF-018	*$75*	DBFG 018	*$70*	DBGH 018	*$45*	DBHJ-018	*$100*	DBJK-018	*$115*	DBKL-018	*$125*		
Rect. to Cylindrical Transitions			DBA 030	*$165*	DBB-030	*$165*	DBC-030	*$165*	DBD 030	*$165*	DBE 030	*$165*	DBF-030	*$160*	DBG 030	*$160*			DBJ 030	*$237*				
N to Waveguide Transformers													DBF-057	*$50*	DBG-057	*$39*	DBH-057	*$39*	DBJ-057	*$50*	DBK-057	*$55*	DBL-057	*$78*
•Straight Sections	DBW 210	*$58*	DBA 210	*$34*	DBB 210	*$34*	DBC-210	*$37*	DBD-210	*$37*	DBE-210	*$24*	DBF 210	*$25*	DBG-210	*$23*	DBH-210	*$28*	DBJ 210	*$37*	DBK-210	*$47*	DBL 210	*$60*
90 E-Plane Elbows	DBW 224	*$125*	DBA 224	*$44*	DBB 224	*$44*	DBC-224	*$44*	DBD-224	*$44*	DBE 224	*$39*	DBF-224	*$33*	DBG-224	*$31*	DBH-224	*$35*	DBJ-224	*$49*	DBK-224	*$68*	DBL 224	*$98*
90° H-Plane Elbows	DBW 234	*$125*	DBA-234	*$44*	DBB-234	*$44*	DBC-234	*$44*	DBD 234	*$44*	DBE-234	*$39*	DBF-234	*$33*	DBG 234	*$31*	DBH 234	*$35*	DBJ 234	*$49*	DBK-234	*$68*	DBL-234	*$98*
Rotating Joints 90-90									DBD-266-1	*$322*	DBE 266-1	*$312*	DBF 266-1	*$286*	DBG-266-1	*$228*	DBH-266-1	*$255*	DBJ-266 1	*$508*	DBK-266-1	*$358*	DBL-266 1	*$435*
Rotating Joints 90-Col									DBD 266 2	*$342*	DBE-266-2	*$332*	DBF-266-2	*$311*	DBG-266-2	*$285*	DBH 266-2	*$318*	DBJ-266-2	*$400*	DBK-266-2	*$468*	DBL 266-2	*$615*
Rotating Joints Col -90									DBD 266-3	*$342*	DBE 266-3	*$332*	DBF 266-3	*$311*	DBG-266-3	*$285*	DBH 266-3	*$318*	DBJ-266-3	*$400*	DBK-266 3	*$468*	DBL-266-3	*$615*
Rotating Joints Col.-Col.									DBD-266-4	*$362*	DBE 266 4	*$352*	DBF 266-4	*$336*	DBG-266-4	*$337*	DBH-266-4	*$386*	DBJ-266-4	*$492*	DBK-266-4	*$578*	DBL-266-4	*$795*
90° Twisted Sections	DBW-274	*$117*	DBA-274	*$44*	DBB-274	*$44*	DBC-274	*$44*	DBD-274	*$44*	DBE 274	*$39*	DBF 274	*$33*	DBG-274	*$31*	DBH-274	*$35*	DBJ 274	*$53*	DBK-274	*$75*	DBL 274	*$110*
Bulkhead Flanges			DBA 275	*$50*	DBB 275	*$50*	DBC 275	*$50*	DBD 275	*$50*	DBE 275	*$46*	DBF-275	*$41*	DBG-275	*$37*	DBH-275	*$48*	DBJ-275	*$61*	DBK-275	*$74*	DBL-275	*$108*
Bulkhead Flanges with Seals			DBA-275-1	*$86*	DBB-275-1	*$86*	DBC 275-1	*$80*	DBD 275 1	*$88*	DBE-275-1	*$84*	DBF-275-1	*$89*	DBG-275-1	*$71*								
Pressurizing Units			DBA-276	*$65*	DBB 276	*$65*	DBC 276	*$55*	DBD-276	*$49*	DBE-276	*$41*	DBF-276	*$40*	DBG-276	*$38*	DBH-276	*$43*	DBJ-276	*$52*	DBK-276	*$63*	DBL-276	*$75*
Crystal Mounts & Multipliers																								
Crystal Mounts			DBA-310	*$98*	DBB-310	*$93*	DBC 310	*$88*	DBD-310	*$83*	DBE-310	*$80*	DBF-310	*$80*	DBG 310	*$55*	DBH-310	*$66*	DBJ 310	*$75*	DBK-310	*$88*	DBL-310	*$128*
Crystal Mts., thru Guide, w/Xtal	DBW-312	*$272*	DBA 312	*$272*	DBB 312	*$272*	DBC 312	*$272*	DBD-312	*$272*														
Crystal Mounts Movable Short	DBW-313	*$307*	DBA-313	*$130*	DBB-313	*$125*	DBC-313	*$120*	DBD-313	*$110*	DBE 313	*$110*	DBF-313	*$110*	DBG-313	*$79*	DBH-313	*$125*	DBJ-313	*$140*				
Tunable Crystal Mounts			DBA-319	*$234*	DBB-319	*$229*	DBC 319	*$224*	DBD-319	*$214*	DBE-319	*$214*	DBF-319	*$220*	DBG-319	*$190*	DBH-319	*$204*	DBJ-319	*$224*	DBK-319	*$244*	DBL-319	*$300*
Crystal Multipliers					DBBW-350	*$453*	DBCA-350	*$328*	DBDB-350	*$328*	DBEC 350	*$328*	DBFC-350	*$273*	DBGE-350	*$268*	DBHF-350	*$218*	DBJF-350	*$292*	DBKG-350	*$309*	DBLJ-350	*$452*
Power Absorbing Units																								
Precision Attenuators	DBW-410	*$537*	DBA-410	*$358*	DBB-410	*$358*	DBC 410	*$358*	DBD-410	*$358*	DBE-410	*$358*	DBF-410	*$270*	DBG 410	*$250*	DBH-410	*$275*	DBJ-410	*$310*	DBK-410	*$325*	DBL-410	*$380*
Variable Attenuators	DBW-430	*$275*	DBA 430	*$150*	DBB-430	*$130*	DBC 430	*$120*	DBD-430	*$115*	DBE 430	*$110*	DBF-430	*$220*	DBG-430	*$200*	DBH-430	*$225*	DBJ 430	*$260*	DBK-430	*$277*	DBL 430	*$315*
Variable Attenuators, Calibrated			DBA-430-1	*$178*	DBB-430-1	*$158*	DBC-430-1	*$148*	DBD-430-1	*$143*	DBE-430-1	*$138*												
Fixed Attenuators			DBA 440A	*$98*	DBB-440A	*$93*	DBC 440A	*$88*	DBD 440A	*$83*	DBE-440A	*$83*	DBF 440A	*$58*	DBG 440A	*$52*	DBH-440A	*$58*	DBJ-440A	*$66*	DBK-440A	*$75*	DBL 440A	*$85*
Low Power Terminations	DBW-450	*$105*	DBA-450	*$75*	DBB-450	*$65*	DBC-450	*$55*	DBD 450	*$44*	DBE 450	*$35*	DBF-450	*$35*	DBG-450	*$28*	DBH 450	*$33*	DBJ-450	*$40*	DBK-450	*$49*	DBL-450	*$65*
Movable Low Power Terminations			DBA 456A	*$115*	DBB-456A	*$105*	DBC 456A	*$95*	DBD 456A	*$75*	DBE-456A	*$68*	DBF 456A	*$78*	DBG 456A	*$72*	DBH-456A	*$87*	DBJ-456A	*$96*	DBK-456A	*$110*	DBL 456A	*$140*
Movable Term. with Extension			DBA-456	*$132*	DBB-456	*$122*	DBC 456	*$112*	DBD-456	*$92*	DBE 456	*$85*	DBF 456	*$103*	DBG-456	*$95*	DBH-456	*$115*	DBJ-456	*$133*	DBK 456	*$157*	DBL-456	*$213*
Movable Term. with Ext. & Vernier			DBA 456-1	*$156*	DBB-456-1	*$146*	DBC-456-1	*$136*	DBD-456 1	*$116*	DBE-456-1	*$109*	DBF 456-1	*$127*	DBG-456-1	*$119*	DBH-456-1	*$139*	DBJ-456-1	*$157*	DBK-456-1	*$181*	DBL-456-1	*$237*
Tunable Low Power Terminations			DBA-459	*$205*	DBB-459	*$195*	DBC-459	*$185*	DBD-459	*$175*	DBE 459	*$175*	DBF 459	*$160*	DBG-459	*$160*	DBH 459	*$162*	DBJ-459	*$182*	DBK-459	*$198*	DBL-459	*$266*
High Power Terminations			DBA-460	*$120*	DBB-460	*$110*	DBC-460	*$100*	DBD-460	*$100*	DBE-460	*$90*	DBF-460	*$80*	DBG-460	*$75*	DBH-460	*$88*	DBJ-460	*$125*	DBK-460	*$129*	DBL-460	*$150*
Horns																								
Pickup Horns			DBA-510	*$83*	DBB-510	*$83*	DBC-510	*$83*	DBD-510	*$83*	DBE 510	*$83*	DBF-510	*$72*	DBG-510	*$71*	DBH 510	*$75*	DBJ-510	*$80*	DBK-510	*$90*	DBL-510	*$110*
Standard Gain Horns, 10 DB, 15 DB	DBW-520	*$180*	DBA 520	*$92*	DBB-520	*$92*	DBC 520	*$92*	DBD 520	*$92*	DBE-520	*$92*	DBF-520	*$84*	DBG-520	*$82*	DBH-520	*$88*	DBJ-520	*$94*	DBK-520	*$116*	DBL-520	*$140*
Standard Gain Horns, 20 DB			DBA 520	*$106*	DBB-520	*$106*	DBC-520	*$106*	DBD-520	*$106*	DBE 520	*$106*	DBF-520	*$95*	DBG-520	*$94*	DBH-520	*$99*	DBJ-520	*$121*	DBK-520	*$195*	DBL-520	*$255*
Conical Horns			DBA 530	*$165*	DBB-530	*$165*	DBC 530	*$165*	DBD 530	*$165*	DBE-530	*$165*	DBF-530	*$182*	DBG 530	*$178*			DBJ 530	*$204*				
Tees, Junctions and Mixers																								
E-Plane Tees	DBW-610	*$150*	DBA 610	*$65*	DBB-610	*$60*	DBC-610	*$58*	DBD-610	*$58*	DBE-610	*$51*	DBF-610	*$41*	DBG-610	*$38*	DBH-610	*$46*	DBJ-610	*$61*	DBK-610	*$80*	DBL-610	*$105*
Waveguide Switches, 2 Way			DBA-616	*$600*	DBB 616	*$600*	DBC-616	*$600*	DBD-616	*$554*	DBE-616	*$554*	DBF-616	*$537*	DBG-616	*$537*	DBH-616	*$554*	DBJ-616	*$651*	DBK-616	*$686*	DBL-616	*$835*
Waveguide Switches, 4 Way			DBA-617	*$590*	DBB-617	*$590*	DBC-617	*$590*	DBD-617	*$544*	DBE-617	*$544*	DBF-617	*$527*	DBG-617	*$530*	DBH-617	*$546*	DBJ-617	*$644*	DBK-617	*$671*	DBL-617	*$822*
H-Plane Tees	DBW-620	*$150*	DBA-620	*$65*	DBB 620	*$60*	DBC-620	*$58*	DBD-620	*$58*	DBE-620	*$51*	DBF-620	*$41*	DBG-620	*$38*	DBH-620	*$46*	DBJ-620	*$61*	DBK-620	*$80*	DBL 620	*$105*
Basic Directional Couplers			DBA-630	*$135*	DBB-630	*$125*	DBC-630	*$115*	DBD 630	*$110*	DBE-630	*$77*	DBF 630	*$61*	DBG-630	*$60*	DBH-630	*$67*	DBJ-630	*$82*	DBK-630	*$110*	DBL-630	*$160*
Directional Couplers, Flg. to Term			DBA-631	*$145*	DBB 631	*$135*	DBC 631	*$125*	DBD-631	*$120*	DBE-631	*$86*	DBF-631	*$68*	DBG-631	*$67*	DBH-631	*$76*	DBJ-631	*$89*	DBK 631	*$119*	DBL 631	*$173*
Directional Couplers, Coax to Term													DBF 632	*$100*	DBG 632	*$90*	DBH-632	*$106*	DBJ-632	*$119*	DBK-632	*$146*	DBL-632	*$216*
Directional Couplers, Xtal. to Flg			DBA-633	*$195*	DBB-633	*$185*	DBC 633	*$175*	DBD-633	*$170*	DBE 633	*$150*	DBF-633	*$125*	DBG-633	*$105*	DBH-633	*$116*	DBJ 633	*$140*	DBK-633	*$170*	DBL 633	*$248*
Directional Couplers, Xtal. to Term			DBA-634	*$205*	DBB-634	*$195*	DBC-634	*$185*	DBD 634	*$180*	DBE-634	*$159*	DBF-634	*$132*	DBG-634	*$112*	DBH-634	*$124*	DBJ-634	*$147*	DBK-634	*$179*	DBL-634	*$261*
Magic Tees	DBW-650	*$225*	DBA-650	*$83*	DBB-650	*$83*	DBC 650	*$85*	DBD-650	*$83*	DBE-650	*$66*	DBF-650	*$56*	DBG-650	*$52*	DBH-650	*$65*	DBJ-650	*$80*	DBK 650	*$100*	DBL 650	*$150*
Matched Magic Tees			DBA-655	*$190*	DBB 655	*$180*	DBC-655	*$170*	DBD 655	*$160*	DBE-655	*$150*	DBF-655	*$90*	DBG-655	*$87*	DBH-655	*$100*	DBJ-655	*$115*	DBK-655	*$140*	DBL-655	*$185*
Balanced Crystal Mixers			DBA-665	*$395*	DBB-665	*$395*	DBC-665	*$395*	DBD-665	*$395*	DBE-665	*$375*	DBF 665	*$300*	DBG-665	*$250*	DBH-665	*$292*	DBJ 665	*$303*	DBK-665	*$326*	DBL-665	*$395*

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Size Designation Frequency Band in KMC Waveguide Nomenclature	DBW 90-140 RG-138/U		DBA 60-90 RG-99/U		DBB 50-75 RG-98/U		DBC 33-50 RG-97/U		DBD 26.5-40 RG-96/U		DBE 18-26.5 RG-53/U	
	Cat. No	*Price*	Cat. No	*Price*	Cat. No.	*Price*	Cat. No	*Price*	Cat. No	*Price*	Cat. No	*Price*
Frequency Meters												
Precision Cavity Wavemeters, Reaction Type	DBW-715-1	*$1,109*	DBA-715-1	*$541*	DBB-715-1	*$541*	DBC-715-1	*$541*	DBD-715-1	*$541*	DBE-715-1	*$541*
Absorption Type	DBW-715-2	*$1,220*	DBA-715-2	*$575*	DBB-715-2	*$575*	DBC-715-2	*$575*	DBD-715-2	*$575*	DBE-715-2	*$575*
Transmission Type			DBA-715-3	*$580*	DBB-715-3	*$580*	DBC-715-3	*$580*	DBD-715-3	*$580*	DBE-715-3	*$580*
Reference Cavity, Reaction Type			DBA-715-1A	*$525*	DBB-715-1A	*$525*	DBC-715-1A	*$525*	DBD-715-1A	*$525*	DBE-715-1A	*$525*
Reference Cavity, Absorption			DBA-715-2A	*$560*	DBB-715-2A	*$560*	DBC-715-2A	*$560*	DBD-715-2A	*$560*	DBE-715-2A	*$560*
Reference Cavity, Transmission			DBA-715-3A	*$565*	DBB-715-3A	*$565*	DBC-715-3A	*$565*	DBD-715-3A	*$565*	DBE-715-3A	*$565*
Impedance Meters												
Precision Standing Wave Detectors, Complete	DBW-825	*$895*	DB4-825	*$610*	DBB-825	*$610*	DBC-825	*$610*	DBD-825	*$564*	DBE-825	*$564*
Carriage Units Only	DB-820	*$327*	DB-820	*$327*	DB-820	*$327*	DB-820	*$327*	DB-820	*$327*	DB 820	*$327*
Waveguide Sections	DBW-821	*$350*	DBA-821	*$206*	DBB-821	*$206*	DBC-821	*$206*	DBD-821	*$179*	DBE-821	*$179*
Broadband Probes	DBW-822	*$250*	DBA-822	*$94*	DBB-822	*$94*	DBC-822	*$94*	DBD-822	*$75*	DBE-822	*$75*
Phase Shifters, Tuners & Shorts												
Phase Shifters	DBW-915	*$275*	DBA-915	*$150*	DBB-915	*$130*	DBC-915	*$120*	DBD-915	*$115*	DBE-915	*$110*
Calibrated Phase Shifters	DBW-915-1	*$355*	DBA-915-1	*$180*	DBB-915-1	*$160*	DBC-915 1	*$150*	DBD-915-1	*$145*	DBE-915-1	*$140*
Variable Stub Tuners			DBA-919	*$148*	DBB-919	*$148*	DBC-919	*$148*	DBD-919	*$148*	DBE-919	*$148*
Cylindrical Phase Shifters			DBA-930	*$165*	DBB-930	*$165*	DBC-930	*$165*	DBD-930	*$165*	DBE-930	*$165*
Fixed Shorts			DBA-960	*$6*	DBB-960	*$6*	DBC-960	*$6*	DBD-960	*$6*	DBE-960	*$6*
Movable Shorts	DBW-969A	*$150*	DBA-969A	*$73*	DBB-969A	*$68*	DBC-969A	*$63*	DBD-969A	*$58*	DBE-969A	*$58*
Movable Shorts with Vernier	DBW-969A-1	*$217*	DBA-969A-1	*$97*	DBB-969A-1	*$92*	DBC-969A-1	*$87*	DBD-969A-1	*$82*	DBE-969A-1	*$82*
Movable Shorts with Extension			DBA-969	*$83*	DBB-969	*$78*	DBC-969	*$73*	DBD-969	*$68*	DBE-969	*$68*
Movable Shorts with Ext. & Vernier			DBA-969-1	*$107*	DBB-969-1	*$102*	DBC-969-1	*$97*	DBD-969-1	*$92*	DBE-969-1	*$92*
E-H Plane Tuners	DBW-979	*$380*	DBA-979	*$175*	DBB-979	*$170*	DBC-979	*$165*	DBD-979	*$160*	DBE-979	*$145*
E-H Plane Tuners with Vernier	DBW-979-1	*$450*	DBA-979-1	*$223*	DBB-979-1	*$218*	DBC-979-1	*$213*	DBD-979-1	*$208*	DBE-979-1	*$193*
Accessories												
Adjustable Waveguide Supports, Ultramicrowave ®	DBW-1010	*$6*	DB-1010	*$6*	DB-1010	*$6*	DB-1010	*$6*	DB-1010	*$6*	DB-1010	*$6*
Adjustable Waveguide Supports, Microwave									DB-1010-1	*$14*	DB-1010-1	*$14*
Waveguide Chassis Mounting Stands	DBW-1012	*$10*	DBA-1012	*$10*	DBB-1012	*$10*	DBC-1012	*$10*	DBD-1012	*$10*	DBE-1012	*$10*
Waveguide Fastening Screws, Pr.	DBW-1020	*$1.10*	DBA-1020	*$1.10*	DBB-1020	*$1.10*	DBC-1020	*$1.10*	DBD-1020	*$1.10*	DBE-1020	*$1.10*
Waveguide Window Seals			DBA-1100	*$38*	DBB-1100	*$38*	DBC-1100	*$38*	DBD-1100	*$38*	DBE-1100	*$38*
Electronic Equipment												
I. F. Transformer Box	DB-1502	*$125*										
Remote Control Box	DB-2016	*$250*										
Noise Diode Power Supply	DB-2140	*$200*										

Size Designation Frequency Band in KMC Waveguide Nomenclature	DBF 12.4-18 RG-91/U		DBG 8.2-12.4 RG-52/U		DBH 7.05-10.0 RG-51/U		DBJ 5.85-8.2 RG-50/U		DBK 3.95-5.85 RG-49/U		DBL 2.6-3.95 RG-48/U	
	Cat. No.	*Price*	Cat. No	*Price*	Cat. No	*Price*	Cat. No.	*Price*	Cat. No.	*Price*	Cat. No.	*Price*
Frequency Meters												
Precision Cavity Wavemeters, Reaction Type	DBF-715-1	*$503*	DBG-715-1	*$487*	DBH-715-1	*$525*	DBJ-715-1	*$564*	DBK-715-1	*$613*	DBL-715-1	*$839*
Absorption Type	DBF-715-2	*$536*	DBG-715-2	*$520*	DBH-715-2	*$558*	DBJ-715-2	*$597*	DBK-715-2	*$646*	DBL-715-2	*$883*
Transmission Type	DBF-715-3	*$542*	DBG-715-3	*$525*	DBH-715-3	*$564*	DBJ-715-3	*$608*	DBK-715-3	*$657*	DBL-715-3	*$894*
Reference Cavity, Reaction Type	DBF-715-1A	*$487*	DBG-715-1A	*$470*	DBH-715-1A	*$509*	DBJ-715-1A	*$547*	DBK-715-1A	*$597*	DBL-715-1A	*$800*
Reference Cavity, Absorption	DBF-715-2A	*$520*	DBG-715-2A	*$503*	DBH-715-2A	*$542*	DBJ-715-2A	*$580*	DBK-715-2A	*$630*	DBL-715-2A	*$844*
Reference Cavity, Transmission	DBF-715-3A	*$525*	DBG-715-3A	*$509*	DBH-715-3A	*$547*	DBJ-715-3A	*$591*	DBK-715-3A	*$641*	DBL-715-3A	*$855*
Impedance Meters												
Precision Standing Wave Detectors, Complete	DBF-825	*$525*	DBG-825	*$465*	DBH-825	*$470*	DBJ-825	*$479*				
Carriage Units Only	DB-820	*$327*	DB-820-1	*$267*	DB-820-1	*$267*	DB-820-1	*$267*				
Waveguide Sections	DBF-821	*$152*	DBG-821	*$152*	DBH-821	*$157*	DBJ-821	*$166*				
Broadband Probes	DBF-822	*$61*	DBG-822	*$61*	DBH-822	*$61*	DBJ-822	*$61*				
Phase Shifters, Tuners & Shorts												
Phase Shifters	DBF-915	*$220*	DBG-915	*$200*	DBH-915	*$225*	DBJ-915	*$260*	DBK-915	*$275*	DBL-915	*$315*
Calibrated Phase Shifters	DBF-915-1	*$270*	DBG-915-1	*$250*	DBH-915-1	*$275*	DBJ-915-1	*$310*	DBK-915-1	*$325*	DBL-915-1	*$380*
Variable Stub Tuners	DBF-919	*$152*	DBG-919	*$147*	DBH-919	*$152*	DBJ-919	*$165*	DBK-919	*$180*	DBL-919	*$230*
Cylindrical Phase Shifters	DBF-930	*$160*	DBG-930	*$160*			DBJ-930	*$204*				
Fixed Shorts	DBF-960	*$8*	DBG-960	*$8*	DBH-960	*$9*	DBJ-960	*$10*	DBK-960	*$11*	DBL-960	*$13*
Movable Shorts	DBF-969A	*$63*	DBG-969A	*$60*	DBH-969A	*$76*	DBJ-969A	*$82*	DBK-969A	*$92*	DBL-969A	*$120*
Movable Shorts with Vernier	DBF-969A-1	*$112*	DBG-969A-1	*$110*	DBH-969A-1	*$126*	DBJ-969A-1	*$150*	DBK-969A-1	*$160*	DBL-969A-1	*$188*
Movable Shorts with Extension	DBF-969	*$87*	DBG-969	*$82*	DBH-969	*$104*	DBJ-969	*$118*	DBK-969	*$135*	DBL-969	*$188*
Movable Shorts with Ext. & Vernier	DBF-969-1	*$137*	DBG-969-1	*$132*	DBH 969-1	*$154*	DBJ-969-1	*$186*	DBK-969-1	*$203*	DBL-969-1	*$256*
E-H Plane Tuners	DBF-979	*$165*	DBG-979	*$158*	DBH-979	*$193*	DBJ-979	*$219*	DBK-979	*$252*	DBL-979	*$325*
E-H Plane Tuners with Vernier	DBF-979-1	*$215*	DBG-979-1	*$208*	DBH-979-1	*$250*	DBJ-979-1	*$300*	DBK-979-1	*$335*	DBL-979-1	*$400*
Accessories												
Adjustable Waveguide Supports, Ultramicrowave ®												
Adjustable Waveguide Supports, Microwave	DB-1010-1	*$14*	DB-1010-1	*$14*	DB-1010-1	*$14*	DB-1010-1	*$14*	DB-1010-2	*$14*	DB-1010-2	*$14*
Waveguide Chassis Mounting Stands	DBF-1012	*$10*	DBG-1012	*$11*	DBH-1012	*$12*	DBJ-1012	*$14*	DBK-1012	*$15*	DBL-1012	*$17*
Waveguide Fastening Screws, Pr.	DBF-1020	*$1.10*	DBG-1020	*$1.10*	DBH-1020	*$1.20*	DBJ-1020	*$1.30*	DBK-1020	*$1.30*	DBL-1020	*$1.65*
Waveguide Window Seals	DBF-1100	*$33*	DBG-1100	*$33*	DBH-1100	*$33*						

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measures
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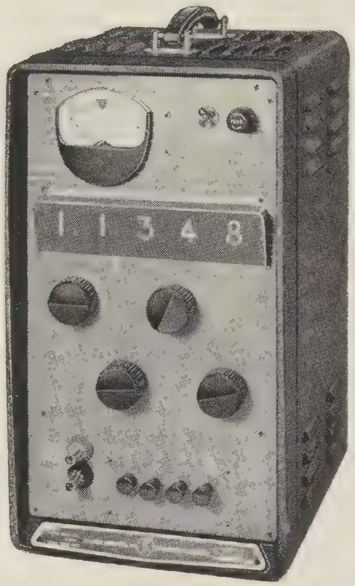
features:

- High accuracy achieved on waveforms in which peak voltage may be as much as twice the RMS. **Not limited to sinusoidal signals.**
- Left-to-right DIGITAL READ-OUT. Fast, simple nulling operation consists of selection of decade range by push-button, and adjustment of four knobs for minimum meter indication. These operations attenuate the input signal to a predetermined value, causing a bridge circuit to be balanced by changing the current through a barretter.
- Temperature-controlled oven contains the barretter and and ambient temperature compensating resistor. Effect of ambient temperature changes is less than 0.005%/° C from 20° C.
- Proper NIXIE digit is lighted automatically while bridge is being balanced. No jitter.
- Rugged, accurate. Doesn't require the extreme care of many laboratory standard instruments. No meter scales to read. Useful for laboratory, production line, and in the field.



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(Continued from page 56A)

Engineering at Illinois Institute of Technology, Chicago.

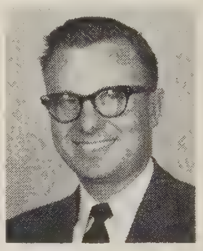
Prior to joining Sylvania, Dr. Raemer was a staff engineer with Cook Research Laboratories, Chicago, Ill., for five years, and a senior physicist with the Bendix Aviation-Research Laboratories for three years. While at Bendix, he performed work on missile seeker development projects.

He is a graduate of Northwestern University, Evanston, Ill., and received the Bachelor's, Master's and Doctor's degrees in physics. He has also taught physics at Northwestern University and applied mathematics at Indiana University, Bloomington.

He is a member of Sigma Xi, and Pi Mu Epsilon, honorary scientific fraternities, and the American Physical Society.

⁂

Henry W. Redlien, Jr., (A'49–M'55), has been named to the position of consulting engineer at Wheeler Laboratories, Inc., a subsidiary of Hazeltine Corporation.



H. W. Redlien, Jr.

He has been project supervisor for the development of one of the several NIKE-ZEUS ground antennas under the Laboratories' subcontract from Bell Telephone Laboratories. He has also worked on microwave components and antennas for the NIKE-AJAX and NIKE HERCULES tracking radars and microwave guidance equipment for the TITAN missile and various space vehicles. He is considered an authority in the field of monopulse theory and practice.

Mr. Redlien was graduated from the Stevens Institute of Technology, Hoboken, N. J., and received the Master's degree from the same institution.

⁂

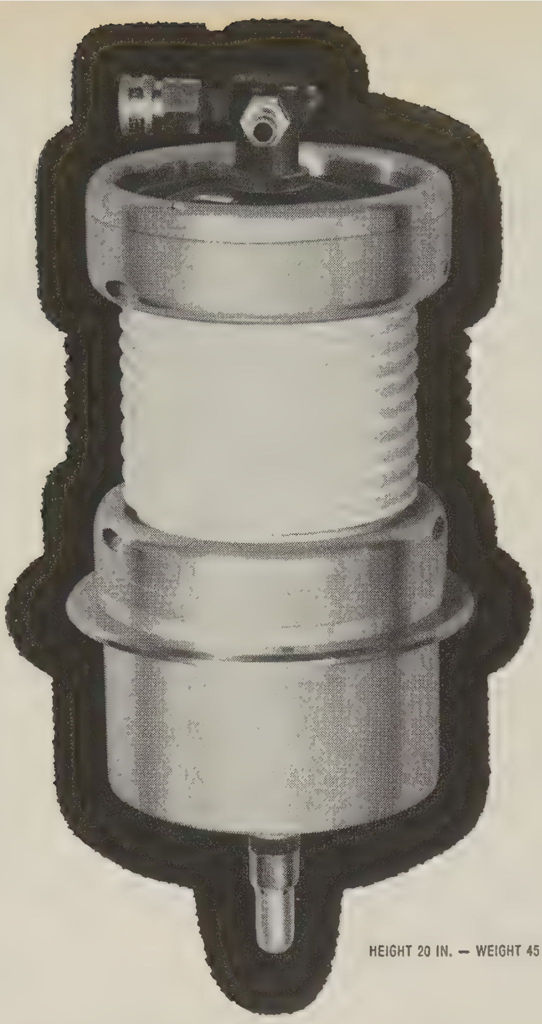
Dr. Peter A. Rizzi (S'49–A'55–M'57–SM'60) has been named President of Microwave Technology, Inc., a recently-formed company at Waltham, Mass.

P. A. Rizzi

In his new post, he will direct the firm's activities in the areas of parametric amplifiers, masers, linear and nonlinear ferrite devices, harmonic generators, filters, semiconductor switches and millimeter components.

In addition, a product line will be developed and the firm will also participate heavily in research and development pro-

(Continued on page 62A)



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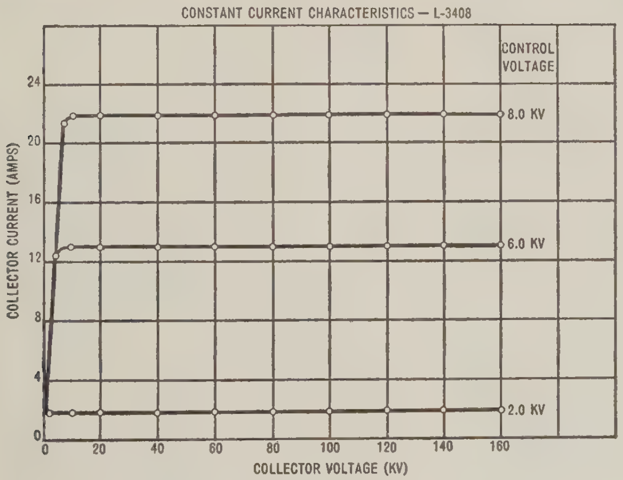
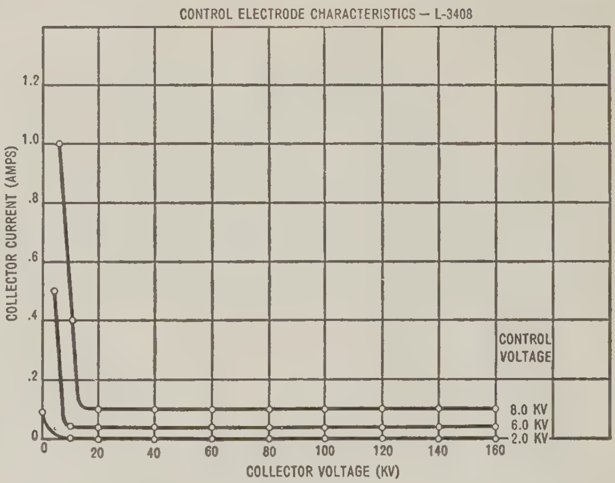


CONSTANT CURRENT CHARACTERISTICS — L-3408



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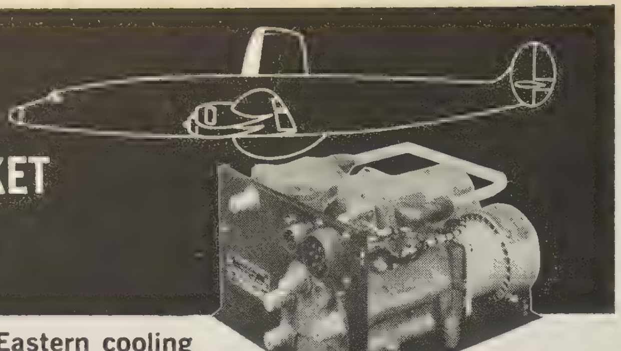


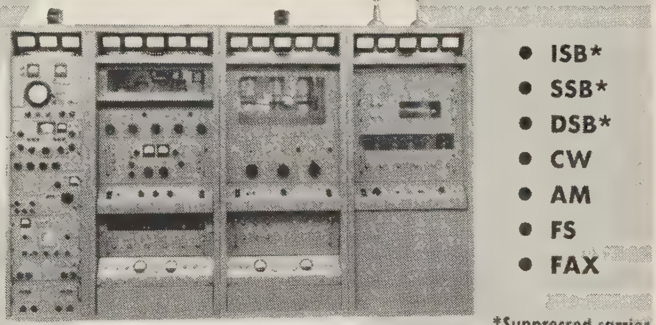
ABOARD A RADAR PICKET PLANE

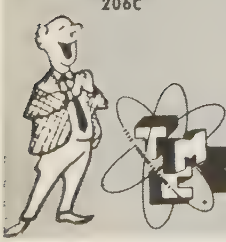
. . . a new Eastern cooling system helps to keep the Philco APS-103 search radar on the lookout for bogies and bandits. The liquid cooling unit has a capacity of 1600 watts, but weighs only 15 lbs., and fits into a compact 5-9/32" x 9-7/8" x 7-7/8" volume. Designed for operation to 50,000 feet, it features an ingenious internal manifold which makes for simplicity, reliability, and which eliminates most internal connections. If you need efficient, miniaturized light weight cooling units for airborne electronics cooling, call on Eastern. Eastern is your perfect source for liquid tube cooling units for capacities from 50 to 20,000 watts.

Eastern AVIATION PRODUCTS

EASTERN INDUSTRIES
100 Skiff Street, Hamden 14, Conn.

West Coast Office:
4203 Spencer St.,
Torrance, Calif.





GPT-40K

AN/FRT-40

- 4 to 28mc.
- 40,000 watts PEP
- ALDC
- Filtered air cooling
- Semi-pressurized cabinet
- Safety interlocks throughout

- ISB*
- SSB*
- DSB*
- CW
- AM
- FS
- FAX

*Suppressed carrier

40,000 WATTS

SEND FOR BULLETIN 206C

The TMC transmitter, Model GPT-40K, is a completely self contained unit including all power supplies and ventilating equipment. All components are housed in four modular assemblies occupying only 40 square feet of floor space.

The transmitter includes equipment for immediate monitoring and testing of all vital operating points.

To provide for complete flexibility in operation, 1 Kw or 10 Kw outputs are readily available for reduced power or emergency operation.

The unit is available with or without synthesizer control.

TMC

THE TECHNICAL MATERIEL CORP.
MAMARONECK, NEW YORK

IRE People

(Continued from page 60A)

grams both for industry and the government.

He comes from the Ewen Knight Corporation of East Natick, Mass., where he was Group Director and responsible for the research and development programs of the Microwave Devices Group.

Prior to joining Ewen Knight in 1958, he was Head of the Microwave Ferrite Section of the Missile Systems Division at Raytheon Company, where he directed the development of ferrite phase shifters, isolators, circulators, modulators, single sideband generators and many other devices.

He was born in Providence, R. I., in 1930. He received the B.S. degree with high honors from the University of Rhode Island, Kingston, in 1951, and the Master's and Doctor's degrees in electrical engineering from Yale University, New Haven, Conn., in 1952 and 1955. His graduate work included a theoretical and experimental investigation of the electromagnetic field in composite ferrite and dielectric structures. During his graduate studies he received the Yale University Scholarship and the Charles Le Geyt Fortescue Fellowship.

He is currently Chairman of the Boston Section of the IRE Professional Group on Microwave Theory and Techniques and on the Editorial Board of the IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES.

Dr. Rizzi is a member of Phi Kappa Phi, Sigma Xi and Tau Beta Pi, and the author of numerous papers in the microwave field.

❖

The appointment of **Philip C. Ross** (SM'55) to the newly-created post of Engineering Manager of the Switch Devices Section has been announced by Electro-Tec Corporation, producer of precision slip ring assemblies and manufacturer of precision components for the electronics industry.

P. C. Ross

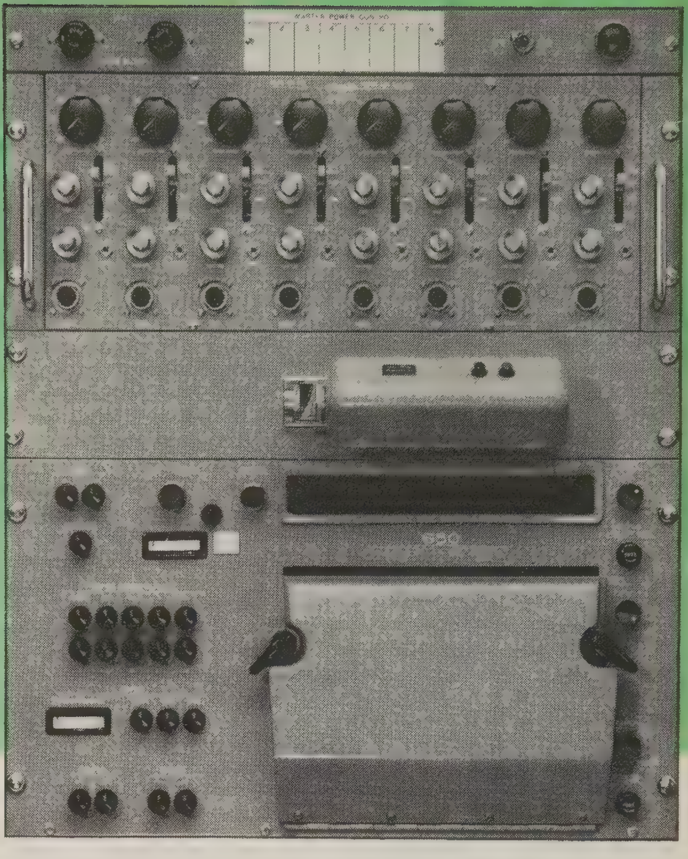
The new section under Mr. Ross will be responsible for the development, design and testing of new switching devices.

He brings to his new post a broad experience in the design, development and marketing of airborne and missile electronics equipment. He comes to the Electro-Tec organization from the General Electric Company, where he was a lead product design engineer. He is a registered professional engineer of New York State, a graduate of Syracuse University, Syracuse, N. Y., and an active member of ASME, AIEE, SAM, AAAS, and the AFCEA.

❖

(Continued on page 64A)

DC to 5000 cycles over an amplitude of 4" peak to peak



NEW SANBORN "650" SYSTEM

OFFERS DIRECT READOUT, 8 TO 24 CHANNELS, ALL SOLID STATE CIRCUITS, FOR RACK MOUNTING OR INDIVIDUAL CASES.

Here's the *one* system that lets you record inputs from DC to 5 KC within 3 db at 4" peak-to-peak amplitudes, without changing galvanometers. The "650" system consists of an 8-channel medium gain, general purpose amplifier unit driving a high speed, high resolution optical oscillographic recorder. It can be easily built into your system, packaged in a mobile cabinet or housed in individual cases. The single-chassis, 7" high amplifier module has 8 separate channels, *complete from floating and guarded inputs to galvanometer outputs;* each channel comprises a front end modulator and input transformer, carrier amplifier, demodulator, filter and driver amplifier. Power Supply and Master Oscillator Power Amplifier are built-in. All amplifier elements are plug-in transistorized units for easy servicing.

Immediately readable recordings are made on 8" wide daylight-loading ultra-violet-sensitive charts which require no chemical development. Features of the 12¼" high recorder unit include 9 electrically controlled chart speeds from ¼" to 100"/sec; calibrated monitoring screen; automatic trace identification and timing lines at 0.01 or 0.1 sec. intervals; amplitude lines spaced 0.1" apart which can be blanked from ¼, ½, ¾ or all of chart. Recorder is available with an 8-, 16- or 24-channel galvanometer block which is then equipped with the number of galvanometer elements desired by the customer. Either the Recorder or Amplifier are also available as individual units for use with other equipment.

SENSITIVITY 20 mv input gives 8" deflection; 12 attenuator steps to X5000, smooth gain control.

INPUT RESISTANCE 100,000 ohms all ranges, floating and guarded; DC source resistance must be kept below 1000 ohms on mv ranges only.

COMMON MODE PERFORMANCE Rejection at least 140 db at DC, tolerance to ±500 volts, max.

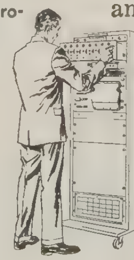
GAIN STABILITY Better than 1% to 50° C. and for line voltage variation from 103 to 127 volts.

LINEARITY 1½% of full scale (8 in.)

NOISE 0.02" peak-to-peak, max.

MONITOR OUTPUT On front panel; provides ±1v full scale across 100,000 ohm load

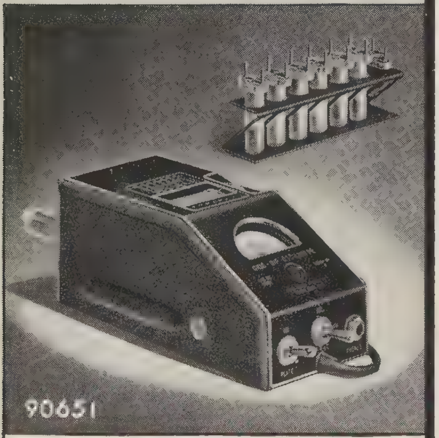
POWER REQUIREMENTS 103-127 volts, 60 cycle AC, 625 watts



Contact your Sanborn Sales-Engineering Representative for complete specifications and applications engineering assistance. Offices throughout the U. S., Canada and foreign countries.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman St., Waltham 54, Massachusetts

Designed for Application



The No. 90651
GRID DIP METER

The No. 90651 MILLEN GRID DIP METER is compact and completely self contained. The AC power supply is of the "transformer" type. The drum dial has seven calibrated uniform length scales from 1.5 MC to 300 MC plus an arbitrary scale for use with the 4 additional inductors available to extend the range to 220 kc. Internal terminal strip permits battery operation for antenna measurement.

JAMES MILLEN
MFG. CO., INC.

MAIN OFFICE AND FACTORY
MALDEN
MASSACHUSETTS

IRE People

(Continued from page 62A)

Dr. Harold Staras (M'50–SM'53) of the RCA Laboratories technical staff at the David Sarnoff Research Center, was recently awarded a Guggenheim Fellowship for one year, beginning September 1, 1961, to undertake "studies of communications systems that utilize new modes of wave propagation."

He will place emphasis in his study upon those communications systems which should prove of most use to the newly emerging states in the world. He expects to center his activities in Israel.

A native of New York, N. Y., Dr. Staras has been associated with the Radio Corporation of America since 1954, and has been engaged in research on propagation phenomena and communications theory. He is a graduate of the City College of New York, and received the M.S. degree in physics from New York University in 1948. In 1955 he received the Ph.D. degree from the University of Maryland, College Park. He is an adjunct professor of electrical engineering at Drexel Institute of Technology, Philadelphia, Pa., a member of the American Physical Society, and Sigma Xi.

❖

J. E. Storer

Dr. James E. Storer (A'54–SM'58) has been named acting director of the Applied Research Laboratory of Sylvania Electric Products Inc. Sylvania is a subsidiary of General Telephone & Electronics Corporation.

The Applied Research Laboratory is the central research facility for Sylvania Electronic Systems, a major division of the company with over-all responsibility for systems management of GT&E's major government projects.

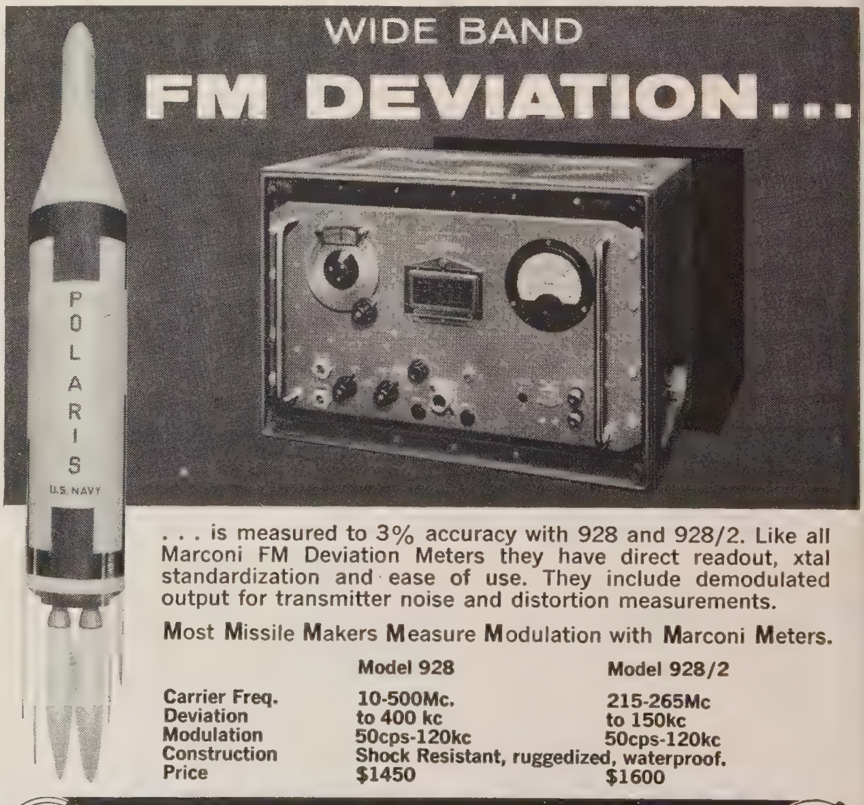
He formerly served as a senior scientist. In 1960, he was one of the first two appointees to that position within GT&E. Prior to joining Sylvania in August, 1957, he served as a consultant to the Applied Research Laboratory, preforming studies relating to military systems analysis.

His subsequent work at the laboratory has included fundamental research in signal analysis and data processing. He has investigated novel digital codes for radar and communications using advanced mathematical techniques. His major contribution has been the synthesis and analysis of new types of digital data communication systems.

A native of Buffalo, N.Y., he received the Bachelor's degree in physics from

(Continued on page 66A)

WIDE BAND
FM DEVIATION...



... is measured to 3% accuracy with 928 and 928/2. Like all Marconi FM Deviation Meters they have direct readout, xtal standardization and ease of use. They include demodulated output for transmitter noise and distortion measurements.

Most Missile Makers Measure Modulation with Marconi Meters.

	Model 928	Model 928/2
Carrier Freq.	10-500Mc.	215-265Mc
Deviation	to 400 kc	to 150kc
Modulation	50cps-120kc	50cps-120kc
Construction	Shock Resistant, ruggedized, waterproof.	
Price	$1450	$1600

MARCONI
INSTRUMENTS

111 CEDAR LANE • ENGLEWOOD, NEW JERSEY
MAIN PLANT, ST. ALBANS, ENGLAND

A VARACTOR FOR EVERY PURPOSE

3 WATTS at 1120 Mc from 7 WATTS at 140 Mc

220 new epitaxial silicon high power varactors in four package styles — subminiature glass case ● double-ended cartridge ● "pill" case ● new "coaxial pill" case — all hermetically sealed, make *this* kind of harmonic generation possible now.

A WIDE VARIETY of PIV ratings and capacitance values allows selection of the optimum diode in each case style for your circuit application.

The data reported below was obtained by the Waveguide Systems Division of Microwave Associates* in a tandem chain of three doubler stages, each using a selected single Microwave Associates' epitaxial silicon high power varactor.

This high power output and remarkable harmonic efficiency was achieved without boosters, without power supply, in passive circuits.

Since the initial introduction of varactors on a commercial basis by Microwave Associates, we have continued to lead the way in varactor technology.

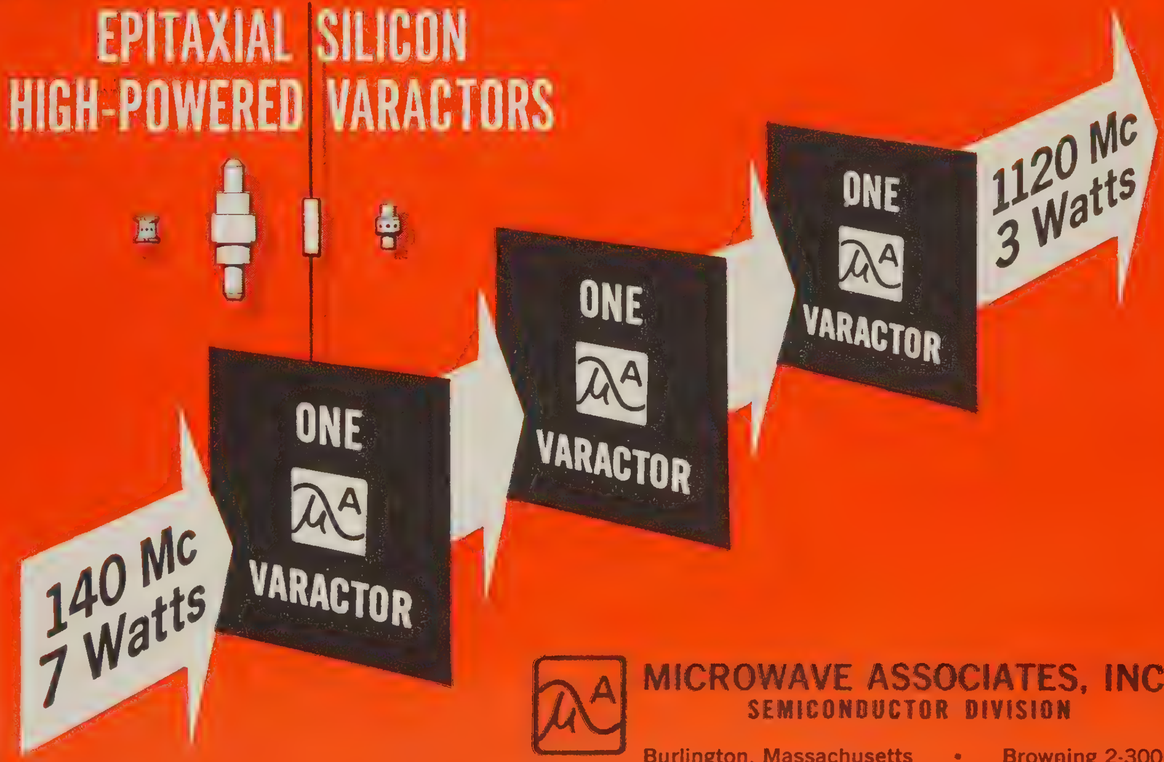
Microwave Associates' unsurpassed varactor circuit capabilities are your assurance of varactors tested to meet specific harmonic generation requirements.

The Waveguide Systems Division of Microwave Associates offers capabilities for the design and delivery of complete harmonic generator circuits.

Write for a copy of "SELECTION OF VARACTORS FOR POWER HARMONIC GENERATION" and for the 1961 Semiconductor Division Short Form Catalog.

* Support received by (USAF) ETL Aeronautical Systems Division Contract #AF33 (616) — 7232.

with MICROWAVE ASSOCIATES EPITAXIAL SILICON HIGH-POWERED VARACTORS



MICROWAVE ASSOCIATES, INC.
SEMICONDUCTOR DIVISION

Burlington, Massachusetts • Browning 2-3000
Western Union Fax • TWX: Burlington, Mass. 942

Export Sales: MICROWAVE INTERNATIONAL CORP., 36 W. 44th Street, N.Y.C., N.Y., U.S.A. Cable MICROKEN

IS *YOUR* COMPANY ON THE *OFFENSE* FOR *DEFENSE?*

SIGNAL is your introduction to the men who control the growing $4 billion dollar government radio-electronics spending

Never before have our armed forces so badly needed the thinking and products of the electronics industry. Advertising in SIGNAL, the official journal of the *Armed Forces Communications and Electronics Association*, puts you in touch with almost 10,000 of the most successful men in the field—every one a prospect for your defense products!

Share in the defense and the profits! Company membership in the AFCEA, with SIGNAL as your spokesman, puts you in touch with government decision-makers!

SIGNAL serves liaison duty between the armed forces and industry. It informs manufacturers about the latest government projects and military needs, while it lets armed forces buyers know what *you* have to offer to contribute to our armed might. SIGNAL coordinates needs with available products and makes developments possible.

But SIGNAL is more than just a magazine. It's *part of an over-all plan!*

A concerted *offensive* to let the government, which has great faith in industry and the private individual producer, know exactly what's available to launch its far-sighted plans. Part of this offensive is the giant AFCEA National Convention and Exhibit (held this year in Washington, D.C., June 6-8) Here, you can *show* what you have to contribute directly to the important buyers. Your sales team meets fellow manufacturers and military purchasers and keeps "on top" of current government needs and market news.

Besides *advertising* in SIGNAL which affords year-round exposure by focusing your firm and products directly on the proper market . . . besides *participation* in the huge AFCEA National Convention and Exhibit . . . the over-all plan of company membership in the AFCEA *gives your firm a highly influential organization's experience and prestige to draw upon.*

As a member, you join some 175 group members who feel the chances of winning million dollar contracts are worth the relatively low investment of time and money. On a local basis, you organize your team (9 of your top men with you as manager and team captain), attend monthly chapter meetings and dinners, meet defense buyers, procurement agents and sub-contractors. Like the other 55 local chapters of the AFCEA, your team gets to know the "right" people.

In effect, company membership in the AFCEA is a "three-barrelled" offensive aimed at putting your company in the "elite" group of government contractors —the group that, for example in 1957, for less than $8,000 (for the full AFCEA plan) made an amazing total of *459.7 million dollars!*

This "three-barrelled" offensive consists of

(1) Concentrated advertising coverage in SIGNAL, the official publication of the AFCEA;

(2) Group membership in the AFCEA, a select organization specializing in all aspects of production and sales in our growing communications and electronics industry; and

(3) Attending AFCEA chapter meetings, dinners and a big annual exposition for publicizing your firm and displaying your products.

If *you're* in the field of communications and electronics . . . and want prestige, contacts and exposure . . . let SIGNAL put your company on the *offense* for *defense!* Call or write for more details—now!

SIGNAL

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72 West 45th Street,
New York 36, New York
MUrray Hill 2-6606
Boston · Chicago ·
Minneapolis · Los
Angeles · San Francisco

IRE People

(Continued from page 66A)

Cornell University, Ithaca, N.Y., and the Master's and Doctor's degrees in applied physics from Harvard University, Cambridge, Mass. He has been an Atomic Energy Commission Fellow, a Research Fellow and lecturer at Harvard, and a John Simon Guggenheim Fellow. During his tenure as Assistant Professor in the Division of Applied Science at Harvard, he served as consultant to Sylvania and other companies.

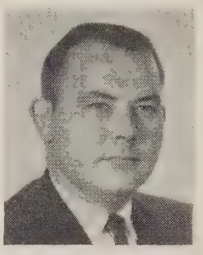
In addition to his numerous technical papers, Dr. Storer has also written a book entitled, "Passive Network Synthesis." He is a member of Sigma Xi, the American Association of Physics Teachers, and the American Institute of Physics.

⁂

The appointment of **Carl N. Sutliff** (S'55–M'59) as engineering applications representative for Cain and Company, instrumentation marketing firm, has been announced.

Previously, he had served as sales engineer for Van Groos Company, and for J. F. O'Halloran and Associates, manufacturers' representatives.

Mr. Sutliff received the bachelor's degree in electrical engineering from California State Polytechnic Institute, Pasadena



C. N. SUTLIFF

⁂

Dr. Albert B. Van Rennes (S'42–A'48–M'50–SM'56) has been appointed by The Bendix Corporation to the new post of Director for European scientific and technical liaison.

He will be responsible for establishing "closer relationships" between the corporation and the European scientific and technical community.

He is returning to Bendix from United Research, Inc., of Cambridge, Mass., where he was Vice President in charge of the company's physical sciences division.

From 1956–1959 he was a member of and later head of the nuclear technology group of the Bendix Research Laboratories division. He received part of his early schooling in the Netherlands. In 1955 he was awarded the Doctor of Science degree from the Massachusetts Institute of Technology, Cambridge. He served on the MIT faculty in the Department of Electrical Engineering from 1946–1956, attaining the rank of Associate Professor. During and after World War II he served with the U. S. Navy. In 1946 he was responsible for the electronic equipment aboard the foreign target vessels at the Bikini atom bomb tests, and for the evaluation of damage to the equipment. He received a Navy letter of citation for his Bikini research.

(Continued on page 68A)

SILICON PLANAR 2N709

6 NSEC τ_s MAX.

MADE POSSIBLE BY FAIRCHILD PLANAR PROCESS

2N709 VERY HIGH SPEED NPN SILICON PLANAR TRANSISTOR ULTRA-FAST SWITCHING APPLICATIONS

JEDEC TO-18 PACKAGE
300 mW POWER DISSIPATION AT 25°C. FREE AIR TEMPERATURE

2N709 CHARACTERISTICS

	Min.	Typ.	Max.	Condition
C_{ob}	....	....	3.0 pf	($V_{CB} = 5.0$ V; I $= 0$ mA)
C_{TE}	....	....	2.0 pf	($V_B = 0.5$ V; $I_C = 0$ mA)
f_T	....	800 mc	....	($V_C = 4.0$ V; $I_C = 5.0$ mA)
τ_s	....	3.0 ns	6.0 ns	($I_B = I_B = I_C = 5.0$ mA)
h_{FE}	20	....	120	($I_C = 10$ mA; $V_{CE} = 0.5$ V)
BV_{CBO}	12 V	....	....	($I_C = 10$ μA; I $= 0$)
I_{CBO}	....	....	100 mμA	($V_{CB} = 5.0$ V; I $= 0$)

ULTRA-FAST SPEED

100-200 mc saturated switching circuits are now made possible and practical because of: typical f_T of 800 mc, average DC propagation delay time of 3 nsec. (6 nsec. max.), 3 pf C_{ob} (max.) and 2 pf C_{TE} (max.).

LOW LEAKAGE

With the 2N709 you can design micropower high speed satellite circuits with minimum allowances for leakage. Provides the parameter stability and uniformity characteristic of Fairchild's silicon Planar devices.

LOW COST

2N709 is on distributor shelves, ready for immediate delivery. You can have this ultra-fast, guaranteed, high-performance device at prices practical for the "breadboard" budget as well as quantity production.

Contact your Fairchild Distributor or Field Office. Or write for complete specifications and pricing information.

SEE US AT WESCON BOOTH NO. 814-16

FAIRCHILD SEMICONDUCTOR

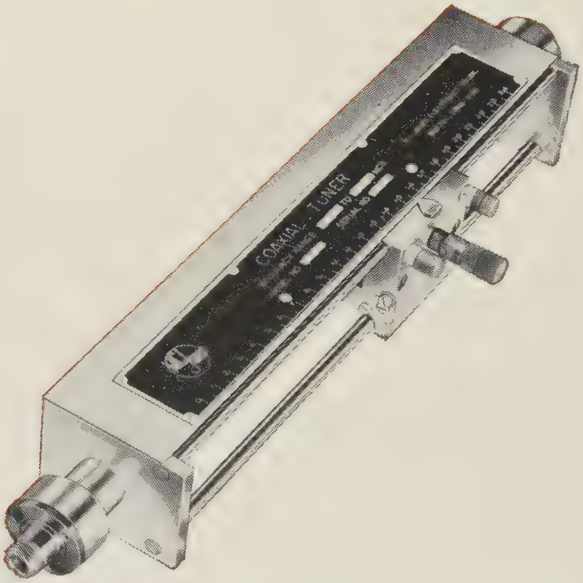
545 WHISMAN ROAD, MOUNTAIN VIEW, CALIF. • YORKSHIRE 8-8161 • TWX: MN VW CAL 853
A DIVISION OF FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

PRECISE *MicroMatch®*

COAXIAL TUNERS

TUNE TO

VSWR 1.000 200-4000 MCS.



MAKES YOUR LOAD A REFLECTIONLESS TERMINATION

DESIGNED FOR USE whenever extremely accurate RF power terminations are required. This laboratory type Coaxial Tuner will tune out discontinuities of 2 to 1 in coaxial transmission line systems or adjust residual VSWR to 1.000 of loads, antennas, etc. May also be used to introduce a mismatch into an otherwise matched system.

M. C. JONES COAXIAL TUNER is designed for extreme ease of operation, with no difficult laboratory techniques involved. Reduces tuning time to a matter of seconds. Graduations on carriage and probe permit resetting whenever reusing the same termination.

SPECIFICATIONS

Impedance	50.0 ohms
Frequency Range	Model 151N 200-1000 Mcs. Model 152N 500-4000 Mcs.
RF Connectors	E1A ⅞" 50.0 ohm Flange plus adapters to N female connector
Power Rating	100 watts
Range of Correction	VSWR as high as 2 may be reduced to a value of 1.000

FOR MORE INFORMATION ON TUNERS, DIRECTIONAL COUPLERS, R. F. LOADS, Etc., PLEASE WRITE TO:

M. C. Jones

M. C. JONES ELECTRONICS CO., INC.
185 N. MAIN STREET, BRISTOL, CONN.
SUBSIDIARY OF THE Bendix CORPORATION

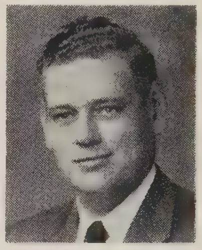
IRE People

(Continued from page 66A)

Dr. Van Rennes has served as a consultant to various commercial organizations and government agencies in the nucleonics field. He is a member of many professional and honorary societies, including the American Society for Engineering Education, American Nuclear Society, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi. He is a former chairman of the IRE Professional Group on Nuclear Science.

❖

The appointment of **William R. Weir** (M'53) to the newly-created position of National Sales Manager for the Semiconductor Division of Sylvania Electric Products Inc., has been announced. Sylvania is a subsidiary of General Telephone & Electronics Corporation.



W. R. WEIR

In his new assignment, he will have his offices at division headquarters in Woburn, Mass. He has been Pacific Regional Sales Manager in semiconductors since 1957.

He joined Sylvania in 1949 as a Junior Engineer at Emporium, Pa. Since that time, he has held various sales positions in New York and Los Angeles.

A native of Weymouth, Mass., Mr. Weir attended Dartmouth College, Hanover, N. H., where he received the Bachelor of Arts degree in mathematics and physics. He has the Master of Science degree in electrical engineering from the Thayer School of Engineering at Dartmouth College.

❖

Dr **Walter Welkowitz** (S'46–A'49–M'55) has been named General Manager of the Instrumentation Division of Gulton Industries, Inc., it has been announced by Dr. L. K. Gulton, President and Chairman of the Metuchen, N J., electronics engineering and manufacturing company. Dr. Welkowitz will will also continue to manage operations of Gulton's Research and Development Laboratory.

W. WELKOWITZ

An authority on transducers and infrared instrumentation, he has been Director of Gulton's R&D laboratory since 1955 and has specialized in transducer design, the industrial applications of ultrasonics and medical instrumentation. At the University of Illinois, Urbana, where he received the Ph.D. degree in electrical engineering, he did extensive research in ul-

(Continued on page 70A)

New

CORNING CYFM CAPACITOR has reliability you can see

You get total protection against environment for less money than ever before

The new Corning CYFM capacitor gives you reliability at a markedly lower cost than that of any like capacitor.

The CYFM goes far beyond MIL-C-11272B specs. It has proved its performance through more than 3,000,000 hours of testing. It took a 50-day MIL moisture test and a 96-hour salt spray test with no measurable effects. We stopped testing only when it became evident that no more significant data could be developed. The CYFM went through other tests, with solvents, fluxes, boiling salt, and steam, to make sure it is the most completely sealed capacitor you can buy.

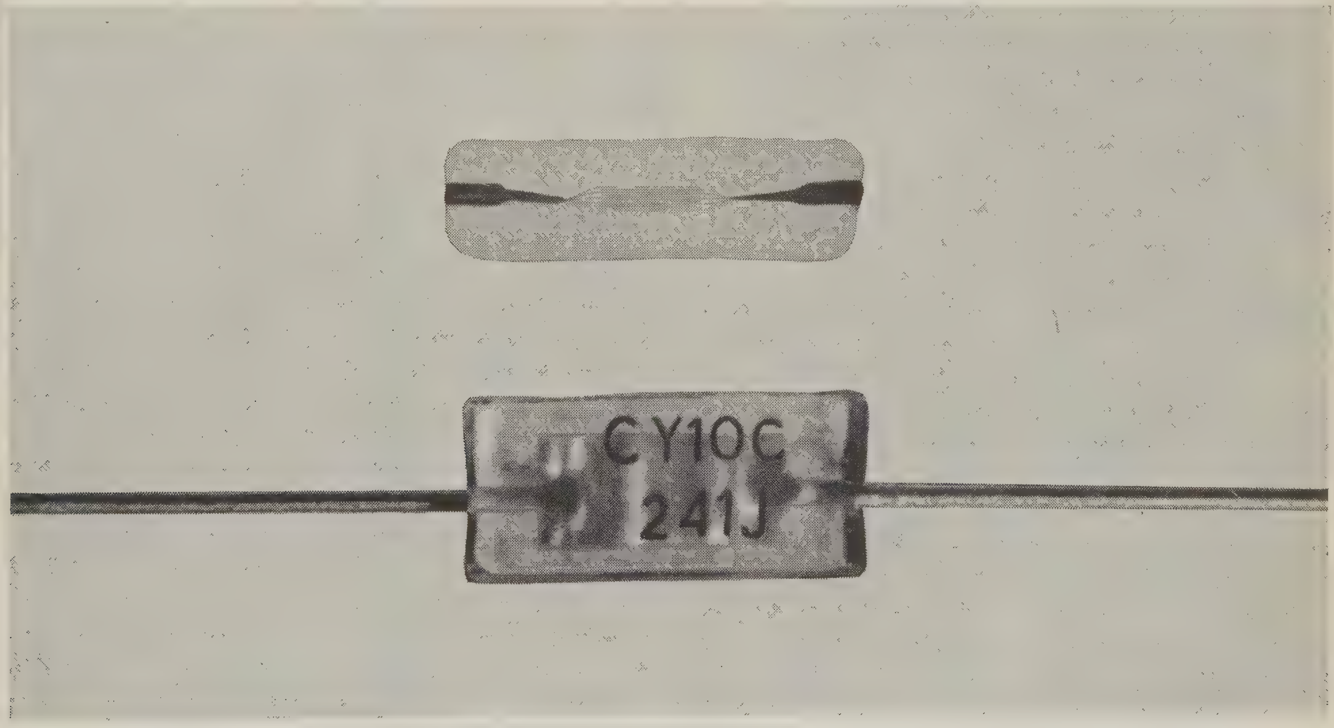
You'll see why the CYFM can take such torture when you check its design. We stack alternate layers of stable ribbon glass and aluminum foil. Then we weld the foils to the bead-terminal assembly, which has a glass bead sealed to the Dumet wire lead. With heat and pressure, the entire capacitive element is frozen in glass for complete protection against environment and for structured protection against physical shock.

True glass-to-metal seals at the weld area and along the leads bar moisture. The seal of the leads to the glass shifts stresses from the leads to the entire monolithic unit, guarding the capacitance area. Of course, you get electrical performance to match this environmental stability, since the CYFM has our glass-foil capacitor construction.

The CYFM is machine made . . . each capacitor is the same as every other, to give you uniformity which hand production cannot match.

You can get immediate delivery on the CYFM in four types. The CYFM-10 gives capacitance values from 0.5 to 300 *pf*; the CYFM-15, from 220 to 1200 *pf*; the CYFM-20, from 560 to 5100 *pf*, and the CYFM-30, from 3600 to 10000 *pf*.

For the rest of the story on this capacitor, send for our data sheet. Write to Corning Glass Works, 542 High St., Bradford, Pa.



This is the CYFM capacitor. 6 times actual size. The dark areas between the ends of the glass and the capacitance element are your visual proof of the complete glass-to-metal seal.

CORNING ELECTRONIC COMPONENTS

CORNING GLASS WORKS, BRADFORD, PA.

ATR PRODUCTS FOR MODERN LIVING

ATR PLUG-IN TYPE PORTABLE
INVERTERS*

A.C. HOUSEHOLD ELECTRICITY
Anywhere . . . *in your own car!*

Operates Standard A.C.
- Record Players
- Dictating Machines
- Small Radios
- Electric Shavers
- Heating Pads, etc.

In your own car or boat!

MODELS
6-RMF (6 volts) 60 to 80 watts. Shipping weight 12 lbs. DEALER NET PRICE. $33.00
12T-RME (12 volts) 90 to 125 watts. Shipping weight 12 lbs. DEALER NET PRICE. $33.00
*Additional Models Available

ATR "A" Battery ELIMINATOR

For Demonstrating and Testing Auto Radios—TRANSISTOR or VIBRATOR OPERATED!

Designed for testing D.C. Electrical Apparatus on Regular A.C. Lines—Equipped with Full-Wave Dry Disc-Type Rectifier, assuring noiseless, interference-free operation and extreme long life and reliability.

MAY ALSO BE USED AS A BATTERY CHARGER
MODEL 610C-ELIF . . . 6 volts at 10 amps. or 12 volts at 6 amps. Shipping weight 22 lbs.
DEALER NET PRICE **$49.95**
MODEL 620C-ELIT . . . 6 volts at 20 amps. or 12 volts at 10 amps. Shipping weight 33 lbs.
DEALER NET PRICE **$66.95**

AUTO-RADIO VIBRATORS ATR

By every test ATR Auto-Radio Vibrators are best! . . . and feature Ceramic Stack Spacers, Instant Starting, Large Oversized Tungsten Contacts, Perforated Reed, plus Highest Precision Construction and Workmanship and Quiet Operation!

There is an ATR VIBRATOR for every make of car!

Ask your distributor for ATR's Low Priced type 1400, 6 volt 4-prong Vibrator; and 1843, 12 volt 3-prong; or 1840, 12 volt 4-prong Vibrator. **THE WORLD'S FINEST!**

There is a trim plate kit for YOUR CAR!

ATR CUSTOMIZED KARADIO

Vibrator-Operated with Tone Control

ATR KARADIO . . . is ideal for small import cars or compact American cars! Unit is completely self-contained—extremely compact! Powerful 8-tube performance provides remarkable freedom from engine, static, and road noises. The ATR Customized Karadio comes complete with speaker and ready to install. Can be mounted in-dash or under-dash—wherever space permits! No polarity problem. Neutral Gray-Tan, baked enamel finish. Overall size, 7" deep, 4" high, and 6½" wide. Shipping weight, radio set, 7 lbs.
Model K-1279—12 for 12V Dealer Net Price . **$33.57**
Model K-1279— 6 for 6V Dealer Net Price. . **$33.57**

Airplane Style Overhead Mounting under Cab Roof

NO PRINTED CIRCUITRY

ATR TRUCK KARADIO

Excellent Tone, Volume, and Sensitivity!

Compact, yet powerful. Fits all trucks, station wagons, most cars and boats. Just drill a ⅝ inch hole in roof and suspend the one-piece unit (aerial, chassis and speaker) in minutes. Watertight mounting assembly holds antenna upright. Yoke-type bracket lets you tilt radio to any angle.

Extra-sensitive radio has 6 tubes (2 double-purpose), over-size Alnico 5 PM speaker for full, rich tone. Big, easy-to-read illuminated dial. Fingertip tuning control. Volume and tone controls. 33-in. stainless steel antenna. Neutral gray-tan enameled metal cabinet, 7 x 6½ x 4 in. high over-all. Shipping weight 10½ lbs.
Model TR-1279—12A for 12V Dealer Net Price **$41.96**
Model TR-1279— 6A for 6V Dealer Net Price **$41.96**

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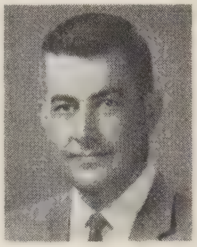
ATR ELECTRONICS, INC.
Formerly American Television & Radio Co
Quality Products Since 1931
ST. PAUL 1, MINNESOTA—U.S.A.

(Continued from page 68A)

trasonics, infrared sources and infrared receivers. He has lectured on acoustics at Columbia University's graduate school of engineering. A member of the Acoustical Society of America, he has published many articles in the fields of ultrasonics, programming and medical electronics.

❖

John L. Wheeler (M'53) has been appointed manager of all Rochester operations of the Information Technology Division of General Dynamics/Electronics, according to an announcement by L. H. Orpin, General Manager of the Division, which has headquarters in San Diego, Calif.


J. L. WHEELER

Included in this operation are engineering, advanced development, and marketing groups working in the fields of data communications, data acquisition and processing, and reactor controls. All are quartered in the company's Rochester, N. Y., plant.

Mr. Wheeler was graduated from Cornell University, Ithaca, N. Y., in 1948, and later that same year joined the Research Department of Stromberg-Carlson, which subsequently merged with General Dynamics. He advanced through several engineering and managerial positions, and was head of the company's Data Equipment Department prior to this new appointment.

❖

John R. Yoder (SM'59) is President and Chief Engineer of the newly-formed Measurement Systems, Inc. The office and laboratory facilities of the firm are in South Norwalk, Conn. The company has been formed to develop and manufacture electro-optical and infrared equipment.

J. R. YODER

Mr. Yoder was formerly Chief of the Advanced Development Section of the Perkin-Elmer Corporation, Norwalk, Conn., where he directed a number of development programs in fields such as infrared surveillance and electro-optical instrumentation. Before joining Perkin-Elmer in 1955 he was Chief Engineer of Stelma, Inc., in Stamford, Conn.

A graduate of Harvard University, Cambridge, Mass. (he received the B.S. degree in physics in 1946), he is a member of the Optical Society of America and the American Rocket Society.

❖

(Continued on page 74A)

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For Research, Testing, Drying, Sterilizing, Baking

TEMPCOR DIFFUSED AIR HEET® CHAMBERS

Tempcor thermocouple indicating-controlling pyrometer . . . with over temperature protection . . . for automatic temperature control to 550°F.

Horizontal convection . . . for fine temperature gradients . . . achieved with diffuser plates and Venturi type air ducts . . . assures uniform temperatures throughout entire work chamber.

Trouble-free pre-lubricated, high volume, low velocity blower.

Nickel-chromium resistance alloy heaters operate with consistency at black heat.

4 sizes: 1½ cu. ft. to 8 cu. ft. . . . 2 and 3 shelves.
Prices: $505.00 to $1050.00, F.O.B. Riverton, N. J.

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Manufacturers of Constant Temperature, Vacuum and Controlled Atmosphere Equipment
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PORTABLE
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DUAL GUN OSCILLOSCOPE

Featuring ⋆ DC to 5 Mc Bandwidth ⋆ 1 mv/cm sensitivity ⋆

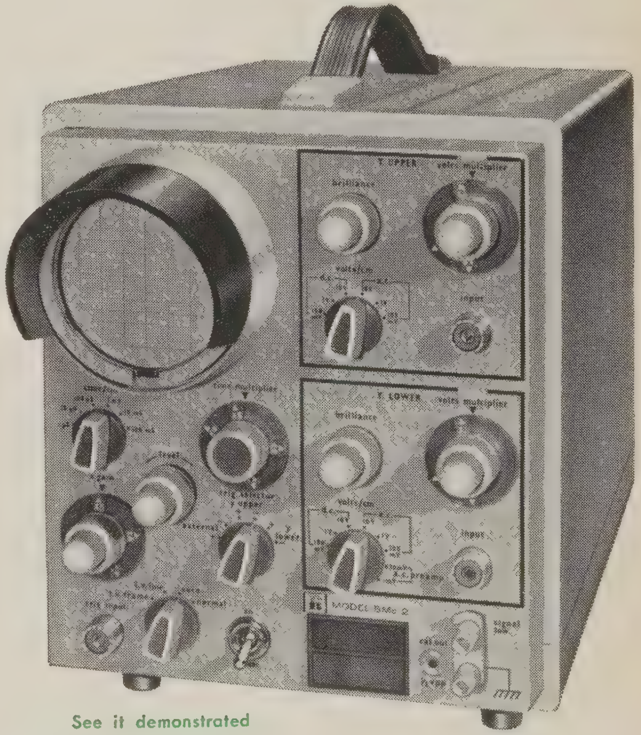
AT HALF THE EXPECTED PRICE $495

Available now for the first time — the only light weight, 5 Mc dual gun oscilloscope with all these features:

VERTICAL AMPLIFIERS: DC to 5 Mc bandwidth (3 db); 70 nanoseconds rise time; 100 v/cm to 100 mv/cm on both amplifiers, 1 mv/cm preamplifier on lower amplifier.
INPUT IMPEDANCE: (each channel) 30 picofarads across 1 Megohm.
HORIZONTAL SWEEP: 1 microsecond/cm to 1 second/cm in 5 steps.
TRIGGER: Internal; free running, or with 0.5 cm excursion by either beam; External; ±0.5 v to 2.5 v ; TV frame and TV line.
WEIGHT: 22 pounds **SIZE:** 9½" x 8½" x 13"
Price: Model 5Mc-2 Oscilloscope with 2 Probes $495.00
Immediate delivery. All prices are quoted f.o.b. Los Angeles, and are subject to change without notice.

For complete information and demonstration contact nearest representative.

Anderson-Stone Engineering, Newton, Mass.
Barnhill Associates, Denver, Colorado; Salt Lake City, Utah; Alamogordo, New Mexico
Brogan Associates, Mineola, Long Island; Syracuse, New York
J. E. Cuesta Company, Paoli, Pennsylvania
Datronics, Houston, Dallas, Fort Worth, Texas
Kittleson Company, Los Angeles, Palo Alto, California
S. S. Lee Associates, Washington, D.C.; Baltimore, Maryland; Winston-Salem, North Carolina; Orlando, Florida
Pivan Engineering, Chicago, Illinois; Indianapolis, Indiana
Satullo Company, Detroit, Michigan; Cincinnati, Cleveland, Ohio; Pittsburgh, Pennsylvania



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The GENERAL INSTRUMENT CAPACITOR DIVISION enters the electronics world with 60 years of experience. Formed by a consolidation of Pyramid and Micamold, the new GENERAL INSTRUMENT CAPACITOR DIVISION combines Pyramid's 23 years of experience and Micamold's 37 years under one, new corporate roof.

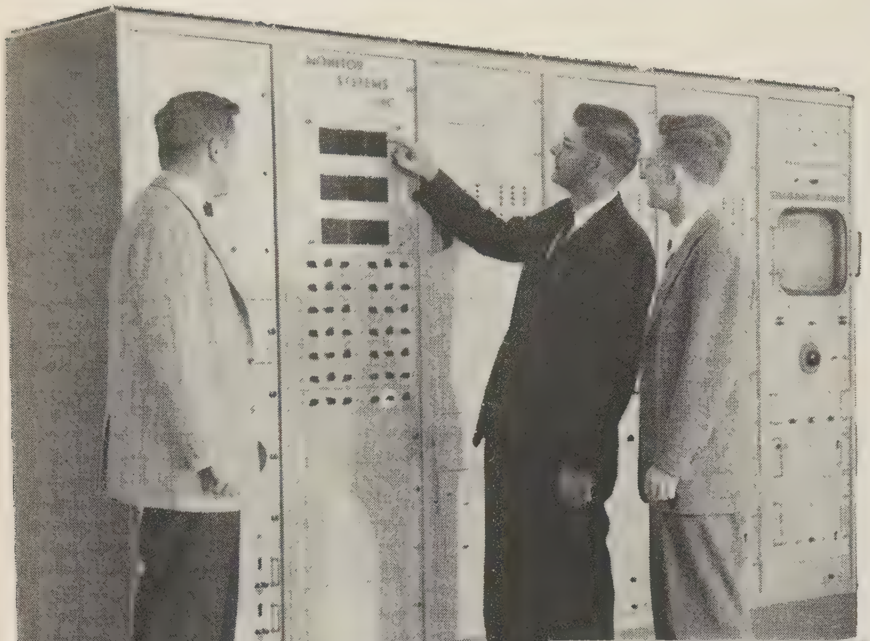
What does this mean to you? ■ You now have a major new source for capacitors...with a product line that meets almost 100% of your capacitor requirements. **(You'll be especially interested in our Tantalums—Dipped Micas—Subminiature Electrolytics and Film Capacitors)...** with modern manufacturing and research facilities capable of handling everything from special high-reliability capacitors to high-quality, large production runs...with experienced and imaginative designers, engineers and technicians approaching each assignment from one point of view—yours!...with a nationwide staff of trained and experienced sales engineers ready to sit down at a moment's notice to help you work out your capacitor problems...with marketing and financial resources that insure a sound pricing policy, and prompt, reliable deliveries, not some of the time, not most of the time, but all the time. ■ Find out how this new "60-year old" source of capacitors can work for you. **Come see us at the WESCON Show, Booth 1912.** Write for engineering bulletins to GENERAL INSTRUMENT CAPACITOR DIVISION, Darlington, S.C.

Order the reliable capacitor from

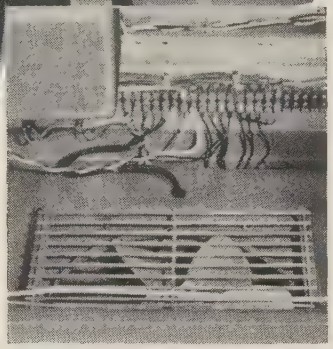
GENERAL INSTRUMENT CAPACITOR DIVISION
GENERAL INSTRUMENT CORPORATION

McLEAN BLOWERS

add to the ULTRA RELIABILITY of this High-Speed Automatic Monitor System

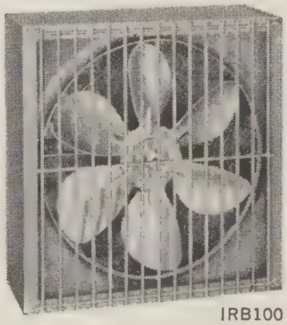


The HAM System built for G. E. Hanford Atomic Products Operation demonstrates the practicality of monitoring nuclear reactor temperatures on a high-speed ultra-reliable basis. The system operates in an air-conditioned room, **but McLEAN blowers are still essential** to prevent overheating and hotspots.



McLean Model IRB100 blower used in the HAM System. One blower is mounted at the base of each of the six racks.

McLEAN stands for *highest reliability* in electronic cooling! That's why Monitor Systems Incorporated of Fort Washington, Pennsylvania, selected McLEAN blowers to insure reliable operation of electronic components in their new High-Speed Automatic Monitor (HAM) System. The System has achieved a previously unattained order of reliability and represents a major advance in computer and monitoring systems. McLEAN is proud of its part in contributing to the reliability of the HAM System.



IRB100

Also a complete line of fractional horsepower motors

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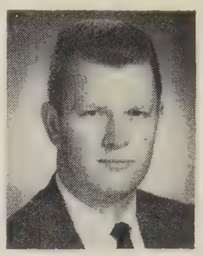
IRE People

(Continued from page 70A)

Richard W. Young (M'57) has joined the field engineering staff of the Sprague Electric Company, it was recently announced. He will be product specialist for silicon dioxide capacitors.



R. W. Young

He comes to Sprague from the Stackpole Carbon Company of St. Mary's, Pa., where he was field engineer for ferrite materials. He has served in various engineering capacities with the Sandia Corporation of Albuquerque, N. M.; Radiation Instrumentation Laboratory of Chicago, Ill., and the geophysical electronics group of the Continental Oil Company, Ponca City, Okla. He also was an instructor in electrical engineering for four years at Catholic University, Washington, D. C. He received the degree of B.S.E.E. from Oklahoma A&M College, Stillwater.

Mr. Young is a member of Sigma Xi, scientific honorary society, and Eta Kappa Nu, honorary electrical engineering society. He served with the U. S. Navy "Seabees" during World War II, and holds the rank of Lt., USNR, in the Navy Civil Engineering Corps.

⁂

The appointment of **Herman A. Affel, Jr.** (SM'55), as Vice President of Auerbach Electronics Corporation was recently announced.

A widely-recognized leader in the computer industry and a pioneer in the application of transistors to data processing equipment, he will direct the operations of the technical staff. Auerbach Electronics Corporation is an organization in the field of information technology, providing complementary services in systems engineering, equipment design, programmed teaching, and product and market planning. Mr. Affel will be located in the Company's Philadelphia headquarters.

Associated with the Philco Corporation for 15 years, he received recognition for his contributions to the development of data processing equipment. Most recently, he was General Manager of the Computer Division of the Philco Corporation which he founded and organized. He was responsible for the engineering, manufacturing, and marketing of an expanded line of commercial data processing equipment including such computers as the S-1000, CXPQ, Philco-2000 series, Philco-2400, C-1000, C-3000, BASICPAC. He also directed government computer development projects.

Prior to this, he was Director of Computing and Control Engineering in the Government and Industrial Division of the Philco Corporation. Manager of the

(Continued on page 76A)

VISIT
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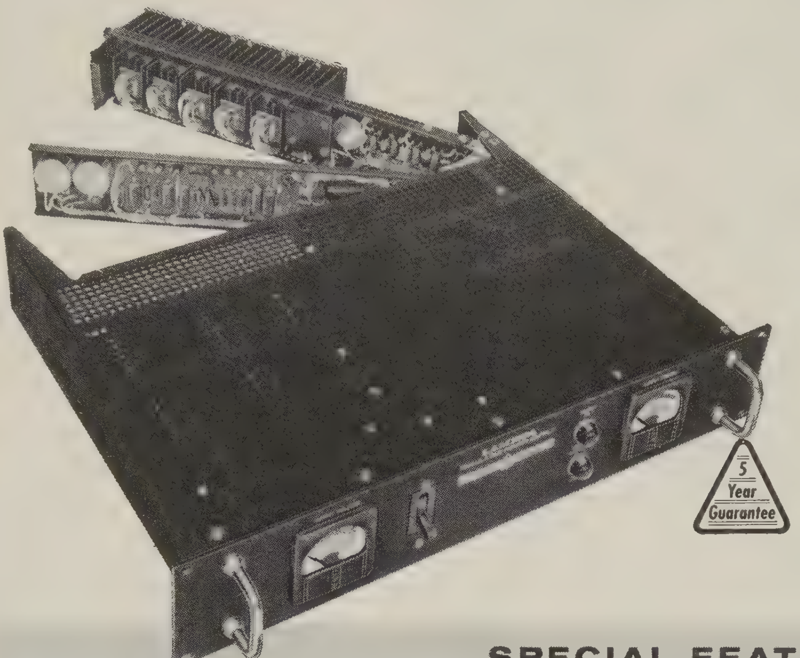
AT WESCON SHOW
BOOTHS 3602-3604

LAMBDA

Convection Cooled Transistorized Regulated Power Supplies



LA SERIES

0- 34 VDC	5 AMP
0- 34 VDC	10 AMP
0- 34 VDC	20 AMP
20-105 VDC	2 AMP
20-105 VDC	4 AMP
20-105 VDC	8 AMP
75-330 VDC	0.8 AMP
75-330 VDC	1.5 AMP
75-330 VDC	3 AMP

SPECIAL FEATURES

- Convection Cooled—No internal blowers or filters—maintenance free
- Ambient 50°C
- No Voltage Spikes or overshoot on "turn on, turn off," or power failure
- Short Circuit Proof
- Remote programming over Vernier band
- Hermetically-sealed transformer designed to MIL-T-27A
- Easy Service Access
- Constant Current Operation—Consult Factory
- Guaranteed 5 years

CONDENSED DATA

DC OUTPUT (Regulated for line and load)

Model	Voltage Range (1)	Vernier Band (2)	Current Range (3)	Price (4)
LA 50-03A	0- 34 VDC	4 V	0- 5 AMP	$ 395
LA100-03A	0- 34 VDC	4 V	0-10 AMP	510
LA200-03A	0- 34 VDC	4 V	0-20 AMP	795
LA 20-05B	20-105 VDC	10 V	0- 2 AMP	350
LA 40-05B	20-105 VDC	10 V	0- 4 AMP	495
LA 80-05B	20-105 VDC	10 V	0- 8 AMP	780
LA 8-08B	75-330 VDC	30 V	0- 0.8 AMP	395
LA 15-08B	75-330 VDC	30 V	0- 1.5 AMP	560
LA 30-08B	75-330 VDC	30 V	0- 3 AMP	860

Regulation (line) .... Less than 0.05 per cent or 8 millivolts (whichever is greater). For input variations from 105-140(5) VAC.

Regulation (load) ...... Less than 0.10 per cent or 15 millivolts (whichever is greater). For load variations from 0 to full load.

Ripple and Noise .... Less than 1 millivolt rms with either terminal grounded.

Temperature Coefficient .... Less than 0.025%/°C.

(1) The DC output voltage for each model is completely covered by four selector switches plus vernier range.

(2) Center of vernier band may be set at any of 16 points throughout voltage range.

(3) Current rating applies over entire voltage range.

(4) Prices are for unmetered models. For metered models add the suffix "M" and add $30.00 to the price.

(5) Except for LA50-03A, LA100-03A, LA200-03A which have AC input voltage of 100-130 VAC. 105-140 VAC available upon request at moderate surcharge.

AC INPUT 105-140 VAC, 60(5) ± 0.3 cycle(6)

(6) This frequency band amply covers standard commercial power line tolerances in the United States and Canada. For operation over wider frequency band, consult factory.

Size

LA 50-03A, LA20-05B, LA 8-08B	3½" H x 19" W x 14⅜" D
LA100-03A, LA40-05B, LA15-08B	7" H x 19" W x 14⅜" D
LA200-03A, LA80-05B, LA30-08B	10½" H x 19" W x 16½" D

Send for new Lambda Catalog 61

LA118A

LAMBDA ELECTRONICS CORP.

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Western Regional Office: 230 North Lake Avenue, Pasadena, California · Phone: Code 213, MUrray 1-2544
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PRODELIN . . . PIONEERING PROGRESS
65
Spir-O-line Semi-flexible Coaxial Cable
Rigid '800' Coaxial Transmission Lines
Spir-O-lok Connectors

PRODELIN Selected for The Great USS Enterprise

The USS Enterprise is a mighty ship with important work to do. Supremely important in the communication complex aboard this vast nuclear-powered aircraft carrier are reliable transmission line systems. Prodelin semi-flexible aluminum Spir-O-line and copper Rigid '800' are now performing in this service.

Spir-O-line semi-flexible coaxial cable, with Spir-O-lok, its companion connector, are a proven combination designed to provide performance unequaled in the transmission line art.

Rigid '800' coaxial transmission lines in copper or aluminum continue to lead the field utilizing reactance compensated pin-type insulators, another proven Prodelin development in rigid, air dielectric coaxial line. Let Prodelin experience give your project reliability and high performance for the most demanding requirements.

MANUFACTURERS OF THE WORLD'S FINEST
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ANTENNAS AND TRANSMISSION LINES

Catalogs available upon request.

- 598 - 2-Way Mobile Antennas
- 603 - Microwave Parabolic Antennas and Accessories
- 595 - Rigid '800' Coaxial Transmission Lines
- 591 - Spir-O-line semi-flexible Coaxial Cable and Spir-O-lok Connectors

Call WYman 1-8600 or write: Prodelin, Inc., 307 Bergen Avenue, Kearny, N.J., U.S.A.
Be sure to see the exhibits at the Prodelin Booth #2701, WESCON, Aug. 22-25, San Francisco, Calif.

IRE People

(Continued from page 74A)

Systems Management Program of the U. S. Navy high altitude bombing equipment, he conceived and directed the development of the first transistorized airborne digital computers, making specific contributions to the important novel circuitry and overall system concepts. He also directed the development, design and manufacture of transistorized general purpose digital computers, ranging from small control computers to a very large-scale complete data processing system. These data processing systems were advanced efforts in the application of transistors. They also involved many new system concepts.

As a Section Manager in the research Division of the Philco Corporation, he directed the development of an airborne radar system, a complete airborne television system, and a color television system, and was responsible for missile studies. For five years, he was involved in research and development for the Bureau of Ordnance, U. S. Navy.

Mr. Affel received the Bachelor of Science degree from the Massachusetts Institute of Technology, Cambridge. He is the holder of patents on the development of microwave antennae. An Educational Counselor at the Massachusetts Institute of Technology, he is also a member of the Massachusetts Institute of Technology Corporation's Visiting Committee for the Department of Physics. He is a member of the Franklin Institute, the American Ordnance Association, the Association of the U. S. Army, and the Electronic Industries Association.

⁂

S. BLOOMENTHAL

Dr. Sidney Bloomenthal (A'27–M'46–SM'59), staff physicist at Automatic Electric Laboratories, Inc., Northlake, Ill., subsidiary of General Telephone & Electronics, was recently honored by the Acoustical Society of America for his many years of research and development in the field of acoustics. A certificate representing twenty-five years membership in the Society was presented to Dr. Bloomenthal Friday, May 12, 1961, at its annual meeting in the Bellevue-Stratford Hotel, Philadelphia, Pa.

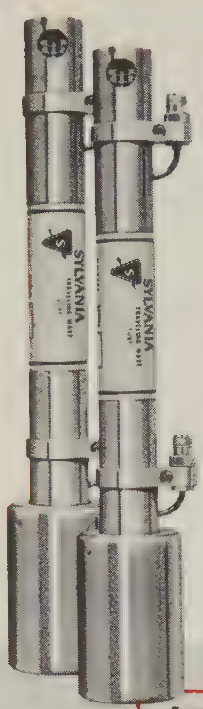
Since receiving the doctorate at the University of Chicago, Chicago, Ill., in 1929, he has concentrated in the field of communications. His early developments included radio resistors, volume controls, methods of growing piezoelectric crystals, and acoustic locators for aircraft; his papers on various of these developments appeared in the *Physical Review* and the

(Continued on page 78A)

MICROWAVE DEVICE NEWS from SYLVANIA

50%
SMALLER!

75%
LIGHTER!



Low Cost, High Performance

PPM-FOCUSED TWT's

for operation from 1 to 12Gc

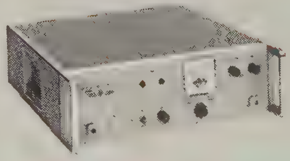
Now available from Sylvania—a new family of traveling wave tubes designed for high-performance microwave amplifier applications where economy, compactness, light weight are vital design considerations.

Less than 4 lbs. in weight and 2¼" in maximum diameter, these TWT's present unusual opportunities for compact design of such end-products as microwave test equipment. No electrical performance is sacrificed in attaining these advantages over bulky, 12-16 lb. solenoid types. In addition, they are priced at less than $1,000 each in quantity.

For further information contact your nearest Sylvania Sales Engineering Office, or write Electronic Tubes Division, Sylvania Electric Products Inc., 1100 Main St., Buffalo 9, N. Y.

Frequency Range (Gc)	Sylvania Type	Power Output	Min. Gain (db)
1-2	TW-4267	15mW	35**
1-2	TW-4268	1W	30*
2-4	TW-4261	10mW	35**
2-4	TW-4260	1W	30*
4-8	TW-4281	10mW	35**
4-8	TW-4278	1W	30*
8-12	TW-4282	5mW	35**
8-12	TW-4273	1W	30*

**small signal gain *at saturation



Hewlett-Packard specified Sylvania TWT's in the new versatile 1-Watt amplifiers, Models 489A (1 to 2 Gc) and 491C (2 to 4 Gc).

AT WESCON—see the Sylvania exhibit, Booth #3201, 3, 5, 7, 9, 11, 12, 3302, 4, 6, 8, 10, 12

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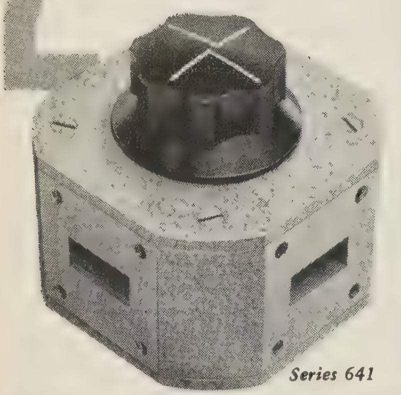

FXR's
WAVEGUIDE
SWITCHES

Series 641

- OPERATION: Full waveguide bandwidth
- RANGE: 3.95 KMc to 40.00 KMc (in 7 sizes)
- CROSSTALK: 60 db min
- VSWR: 1.10 max
- Choice of manual or electrical drive
- High-power capacity

No. 2 of a series of FXR's new precision microwave components designed to meet the ever-growing needs of the microwave industry.

FXR's Waveguide Switches find applications on the test bench and in microwave systems. Operating over the full waveguide frequency ranges, these switches provide trouble-free operation with high isolation and high-power capacity. The milled aluminum waveguide rotor assures low VSWR. For long life it is mounted on ball bearings and is electrically connected to the stator through non-contacting choke sections.

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MODEL NO.	FREQUENCY RANGE KMc	WAVEGUIDE TYPE RG-( )/U	*PRICE (MANUAL)
H641A	3.95- 5.85	49	$350.00
C641A	5.85- 8.20	50	300.00
W641A	7.05-10.00	51	265.00
X641A	8.20-12.40	52	225.00
Y641A	12.40-18.00	91	250.00
K641A, AF	18.00-26.50	53	275.00
U641A, AF	26.50-40.00	96	300.00

*Slightly higher for electrically driven units.

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IRE People

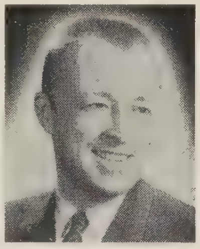
(*Continued from page 76A*)

Journal of Applied Physics. He developed techniques of producing silicon carbide varistors, and has conducted extensive experiments on relay contacts and contacting materials. He holds seven U. S. and many foreign patents.

A twenty-five year member of the Acoustical Society, Dr. Bloomenthal is also a member of the American Physical Society, American Society of Lubrication Engineers, Illinois State Academy of Science, Physics Club of Chicago, and of Sigma Xi, and a Fellow of the American Association for the Advancement of Science. Joining Automatic Electric in 1940 as a research physicist, he was appointed in 1947 to his present position at Automatic Electric Laboratories.

⁂

Motorola Semiconductor Products, Inc., announced that **Bruce B. Burnett** (M'59) has recently been appointed Account Executive in Motorola's eastern regional sales area.



B. B. BURNETT

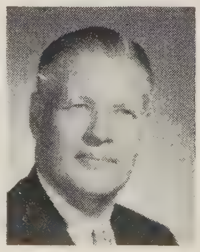
In this new position, he will supervise special accounts in the eastern United States and will be located at the firm's area sales office in Clifton, N. J.

Before joining Motorola, he was associated with Texas Instruments, Inc., as District Sales Manager for semiconductor products. Previously he had been with General Electric Company as sales specialist in the Magnetics Materials Section.

Mr. Burnett received the B.S. degree in engineering from Rensselaer Polytechnic Institute, Troy, N. Y., in 1950.

⁂

Until recently an engineering executive at International Telephone & Telegraph Corporation, **Rodney D. Chipp** (A'34–SM'43–F'55), has left to head the new firm of Rodney D. Chipp & Associates, Consulting Engineers, with headquarters in Bloomfield, N. J.



R. D. CHIPP

In the fields of electronics, communications systems, radio and television broadcasting systems, industrial TV and engineering management, the firm will act as consultant to government and the military as well as to private industry. It will work on both a nationwide and international scale. An unusual range of engineering experience—in planning, design, construction, operation, maintenance and management of the various systems—will be available.

Besides pioneering in television and radar, Mr. Chipp has three decades of experience in design and operation and management of electronic and communications systems. (He was cited during Navy service in World War II for his "splendid design" of radar equipment.)

In his many years with National Broadcasting Company and the Allen B. DuMont Laboratories, he was responsible for the development of operational equipment and techniques, many of which are still standard today. In addition, he has engineered AM, FM and TV broadcasting studios and transmitters, communications networks, radar systems; and (for ITT) large-scale military communications systems. He has been retained as consultant by the U. S. Navy, U. S. Air Force, and many commercial concerns.

While he was Director of Engineering at ITT Communication Systems (a subsidiary set up to develop global communications for the Air Force) he took special leave in 1960 for a month-long study in South America. He had previously traveled widely on surveys of communications and broadcasting systems in Europe, South America, and Central America. He and his wife were selected for "Project Ambassador" sponsored by the National Society of Professional Engineers. They made a detailed report to the Society on the problems faced by engineers overseas, and of how they can improve their relationships with their Latin American counterparts. Their report has been widely discussed and has been used by both technical and government groups.

For the IRE, the National Association of Broadcasters, and the Electronic Industries Association, he has served on many committees concerned with the establishment of standards and systems compatibility. He has also worked as a Committee Member for the International Radio Consulting Committee, an international organization which recommends worldwide technical standards and frequency allocations.

He received his basic technical education at Massachuseetts Institute of Technology, Cambridge, and has supplemented it with professional and graduate courses. He holds the B.S. in physics and is a licensed professional engineer in New York and New Jersey. He is author of more than thirty technical articles, and co-author of a reference book on "Closed Circuit TV Systems Planning."

He was elected a Fellow of the IRE in 1955 for his radar and TV contributions to the Navy. He is still active as a Captain in the Naval Reserve. Mr. Chipp is a member of the National Society of Professional Engineers, the U. S. Naval Institute, the American Institute of Electrical Engineers, the Society of Motion Picture and Television Engineers, and the Association of Federal Communications Consulting Engineers.

⁂

(*Continued on page 81A*)

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IRE DIRECTORY
It's valuable!

NEW—MINCOM SERIES G-100 RECORDER/REPRODUCER

Series G-100 Frequency Response	
Direct:	200 cps to 300 kc at 60 ips
FM (extended):	DC to 20 kc at 60 ips
FM (standard):	DC to 10 kc at 60 ips

Building-block construction; card system record/reproduce modules; just twelve moving parts with four easy adjustments; complete plug-in modular design—everything about this new and outstanding **Mincom Series G-100** emphasizes its reliable simplicity. Here's an all-purpose magnetic tape system for better performance with improved dynamic range. It's planned for easier operation and maintenance with automatic bias and power supply protection; built-in calibration, plus built-in monitor switching; dynamic braking; all-transistorized electronics; fourteen tracks (analog or FM) in one rack. Covering the bandwidths listed at right, G-100 fills the gap between Mincom's Series CA-100 (125 kc-60 ips) and the Series CM-100 (1.2 mc-120 ips). To discover more of this new system's extra capabilities, write today for complete specifications. See us at WESCON, Booth 1806.

3M COMPANY ... WHERE RESEARCH IS THE KEY TO TOMORROW

MINCOM DIVISION **MINNESOTA MINING AND MANUFACTURING COMPANY**

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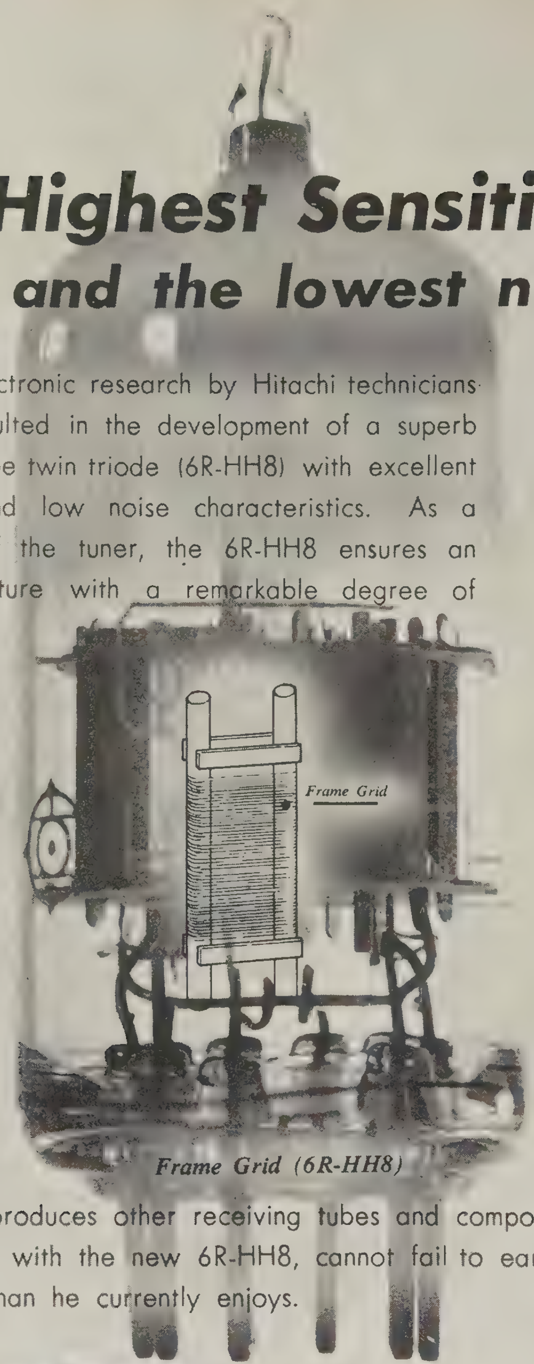
The Highest Sensitivity
and the lowest noise.....

Advanced electronic research by Hitachi technicians has now resulted in the development of a superb frame grid type twin triode (6R-HH8) with excellent high gain and low noise characteristics. As a component of the tuner, the 6R-HH8 ensures an excellent picture with a remarkable degree of definition.



Frame Grid (6R-HH8)

fig. 1 Gain characteristics

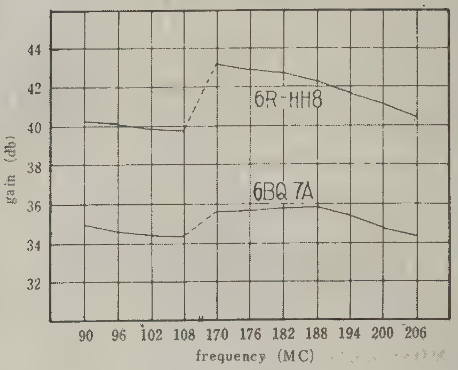
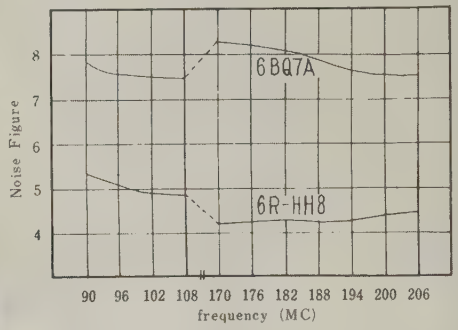


fig. 2 Noise characteristics



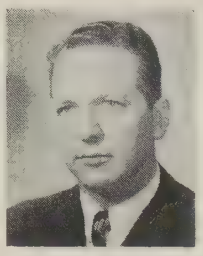
Hitachi also produces other receiving tubes and components for television which, when used together with the new 6R-HH8, cannot fail to earn any maker a market reputation even better than he currently enjoys.

Automatic tube testing equipment

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

IRE People

(Continued from page 78A)



L. P. Brooks

Lorimer P. Brooks (A'50–M'55) has been elected to the Board of Governors of the New York Patent Law Association. He also is Chairman of its committee on Court Practice and Procedure.

He is a member of the law firm of Ward, Neal, Haselton, Orme and McElhannon in New York, N. Y. He received the B.S. degree in electrical engineering from Northeastern University, Boston, Mass., and the L.L.B. degree from Fordham University Law School, New York, N. Y. and did post-graduate work at New York University Law School, N. Y. He is a member of Tau Beta Pi, the American Bar Association and the Aircraft Owners and Pilots Association and is a director of the United Cerebral Palsy Association of Westchester County.

Prior to his present association, Mr. Brooks was a patent attorney with International Telephone and Telegraph Company and an engineer with the Signal Corps, assigned to the Naval Research Laboratories, where he did development work on radar and IFF equipment. He also is a Vice President of Drum Fire, Inc., a manufacturer of electrical appliances.

❖

Appointment of **Allen J. Gardenhour, Jr.** (A'53–M'58), as Northern Regional Manager for Consolidated System Corporation, Pasadena, Calif., was recently announced.

He most recently served CSC in the Washington, D. C., area as Engineering Representative providing technical liaison between the National Aeronautics and Space Administration and CSC in several phases of the space exploration program.

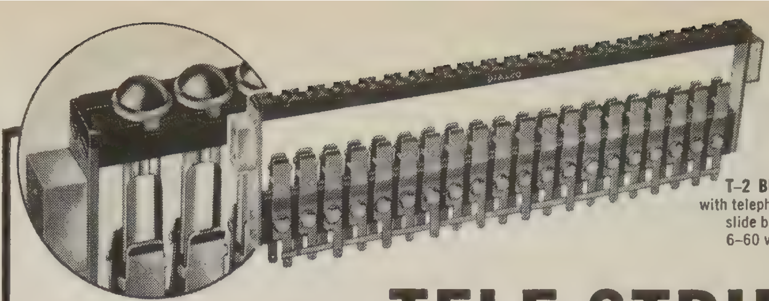
Prior to that, he held key engineering and administrative posts with the U. S. Naval Ordnance Laboratories, where he was responsible for the design and development of production and field test equipment for the LULU project, as well as defining and directing the initial design of Subroc test equipment.

In his new post, he will coordinate marketing, technical liaison, and field service activities for CSC in the north central and eastern United States. He will continue to headquarter in Washington, D. C.

Mr. Gardenhour holds the B.S. degree in electrical engineering from Pennsylvania State University, University Park, and has undertaken graduate work in engineering and business administration at the University of Maryland, College Park. He is a member of the Instrument Society of America.

❖

(Continued on page 83A)



T-2 BULB with telephone slide base; 6-60 volts

DIALCO **Tele-Strip** No. TS 4220.
Accommodates 20 DIALCO Lens Cap Assemblies (Series 402–).
Convex or dome lens; 6 colors.

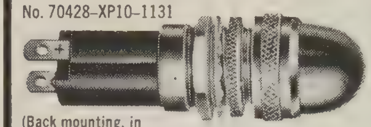
TELE-STRIPS®

(MULTIPLE LAMP INDICATORS)

For switchboards and other applications requiring multiple indication with T-2 lamps.

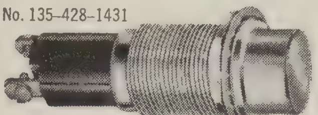
DIALCO **Tele-Strips** are available in several styles, and in sizes to accommodate from 2 to 20 Lampholders per strip. Choice of Lens Caps and Colors, or less lens caps for use with designation cards. Also: **Tele-Strips** made to specifications. Submit problem for recommendations.

No. 70428-XP10-1131



(Back mounting, in 9/16" clearance hole)

No. 135-428-1431



(Front mounting, in 11/16" clearance hole)

INDICATOR LIGHTS

FOR WARNING, SIGNAL AND READOUT APPLICATIONS

Two complete Series: For mounting in 9/16" and 11/16" clearance holes. Wide choice of lens styles and colors. All assemblies are available complete with lamp.

Samples on Request at Once — No Charge

For complete data, request 8-page Catalogue L-164.

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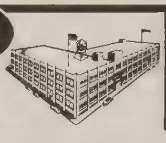

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CORPORATION

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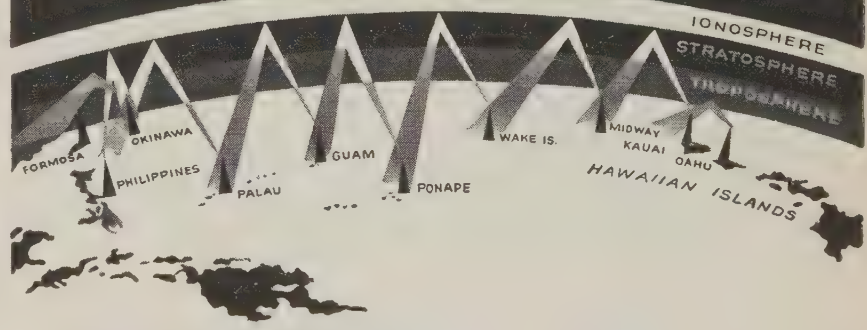
Booths 2519-2521 at the WESCON Show

Another reason . . .
the world becomes smaller



7,500-mile Pacific Scatter Communication System linking major command posts from Hawaii to Formosa was recently designed and built for the U. S. Army Signal Corps

by

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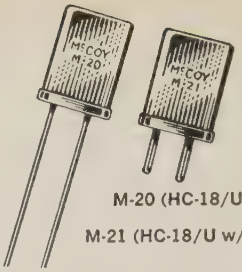
McCoy

CRYSTALS & CRYSTAL FILTERS

Regardless of its size, type, or frequency any crystal bearing the name **McCoy** can be relied upon to deliver the ultimate in frequency control despite wide temperature variations and extreme conditions of shock and vibration.

METAL ENCASED STANDARD SIZE AND MINIATURE CRYSTAL UNITS

shown actual size



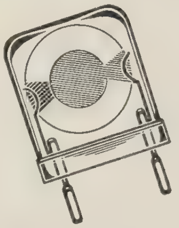
M-1 (HC-6/U)

M-20 (HC-18/U)

M-21 (HC-18/U w/pins)

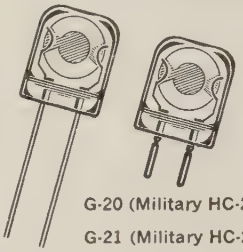
The crystals that made the name of McCoy a synonym for quality. Metal encased, HC-6/U size is available in frequencies from 500.0 kc to 200.00 mc.

Fills the need for miniature crystals in frequencies from 2.5 mc to 200.0 mc. Meets specs MIL-C-3098B and ARINC No. 401.



ALL GLASS STANDARD SIZE AND MINIATURE CRYSTAL UNITS

shown actual size



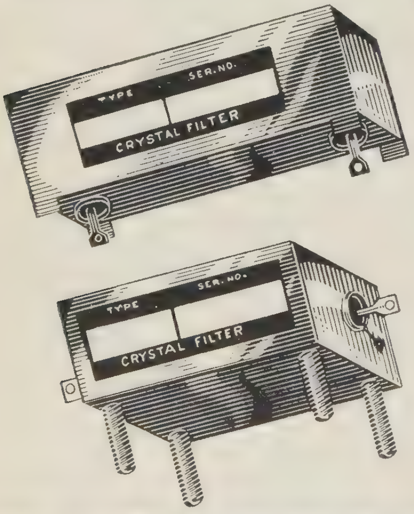
G-1 (Military HC-27/U)

G-20 (Military HC-26/U)

G-21 (Military HC-29/U)

This vacuum sealed, hard glass crystal unit possesses all of the quality features for which the McCoy M-1 is so famous. It has long term frequency stability five times better than the conventional metal types. Available in frequencies from 500 kc to 200 mc.

This vacuum sealed, hard glass crystal unit meets the new CR-73/U and CR-74/U specifications. It has long term frequency stability five times better than the conventional metal type. Available in frequencies from 5000 kc to 200 mc.

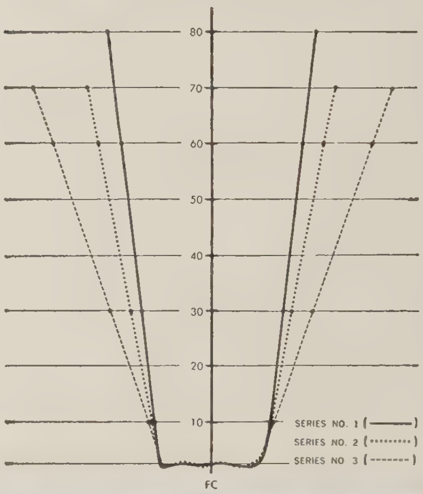


CRYSTAL FILTERS

Our many years experience in designing and producing top quality oscillator crystals have enabled us to develop and produce filters of equal desirability. Current production includes filters in the 1.0 mc to 30 mc range, with bandwidths of .01% to 4.0% of center frequency. A number are available without costly design and prototype charges.

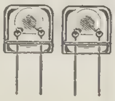
Actual Size for Series 3 Types

SELECTIVITY CURVES



See the **New!**

MICRO MODULE CRYSTALS (GLASS)



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COW PALACE • SAN FRANCISCO, CAL.
AUGUST 22 thru 25   BOOTH NO. 1402

.28" square x .110" thick
frequency range: 7000 kc to 200 mc
Now available in limited quantities

Write today for our free illustrated catalogs which include complete listing of military specifications. For specific needs, write, wire or phone us. Our research section is anxious to assist you.

McCoy

ELECTRONICS CO.
Dept. P-8
MT. HOLLY SPRINGS, PA.
Phone: HUnter 6-3411

(Continued from page 81A)

Robert J. Gilson (SM'55) has been appointed General Manager of the Military Products Division, Rochester, N. Y., of General Dynamics/Electronics, it was recently announced. He was formerly Director of Systems Management for the division.

R. J. Gilson

Prior to joining General Dynamics/Electronics (at that time Stromberg-Carlson) a year and a half ago, he was with Hoffman Electronics Corporation, Los Angeles, Calif., as program director of a major electronic reconnaissance system, and before that, with Litton Industries, Beverly Hills, Calif.

A native of Palo Alto, Calif., Mr. Gilson received the Bachelor's degree in electrical engineering from Montana State College, Bozeman, and the Master's degree in engineering administration from the University of California at Los Angeles. During World War II he served as a radio officer in the Maritime Service. He is a member of the American Institute of Electrical Engineers and the Association of the U. S. Army.

❖

Irving Ginsberg (S'43–A'45) has been appointed Manager of the Buffalo, N. Y., field projects department of the Product Support Organization of Sylvania Electronic Systems, a division of Sylvania Electric Products Inc. Sylvania is a subsidiary of General Telephone and Electronics Corporation.

I. Ginsberg

The Product Support Organization provides field project management throughout the world, including all phases of installation, test, operation, maintenance and training.

Mr. Ginsberg will be responsible for directing all field activities in connection with equipment developed and produced by the Buffalo Operations of Sylvania Electronic Systems.

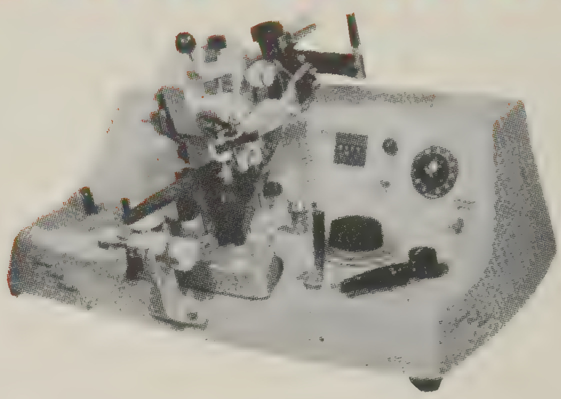
Current Buffalo field activities include flight testing the electronic defense system for the B-58 Hustler bomber at Carswell Air Force Base, Tex., and Bunker Hill Air Force Base, Ind.

He previously served as Supervisor of the Sylvania field programs for the MOBIDIC (mobile digital computer), which is being developed and produced for the U. S. Army Signal Corps, and the Sylvania 9400, a powerful general-purpose digital computer designed to serve as the

(Continued on page 85A)

BOOTH 5119 WESCON

GORMAN
TOROID WINDERS



MODEL 600 WINDS DOWN TO .055" I.D.

GORMAN Machine Corp: 480 S. Main St., Randolph, Massachusetts
WEST COAST: Torrance Municipal Airport—Torrance, Calif.

Another reason...
the world
becomes
smaller

A new Voice of America broadcasting facility in Liberia is being engineered by Page. Three previous VOA stations in Tangier, Okinawa, and the Philippines, bringing together over 100 nations, were designed and built by

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An NEC semiconductor device for every circuit application

The range of semiconductor products at NEC is perhaps the widest of any manufacturer. Entertainment or industrial, standard broadcast frequencies to microwave — NEC has a semiconductor device with the ratings and characteristics for your application. There's a wide selection of current ratings, operating temperatures, and mountings.

These are produced in NEC's new semiconductor plant where crystal surfaces are cleaned by 100 tons of hyper pure water daily. Every seal is tested in krypton isotopes, providing a failure rate suitable for the most critical applications.

A single source for semiconductors can mean a saving in time and costs. Just let NEC know your requirements and full technical data will be sent.

Types of NEC semiconductor devices

• PNP super-grown Germanium transistors • Germanium photo transistors • PNP alloy junction Germanium transistors • Silicon Mesa transistors • Germanium Mesa transistors • Germanium gold-bonded diodes • Silicon rectifiers • Silicon controlled rectifiers • Silicon capacitors • Zener diodes • Germanium point-contact mini-diodes • Silver-bonded diodes • Microwave mixer diodes • Silicon junction mini-diodes

---

Reliability The first NEC transistorized carrier telephone system was an NT & T installation in 1958 between Toyama and Takaoka, a distance of 15 miles. It consists of two terminal stations and a repeater station with 240 channels using 1,600 transistors.

During last 14,000 hours of operation transistor failure has caused only two channel faults. This corresponds to a failure rate of 0.009% per 1,000 hours.

Communications Systems / Electronic Components NEC *Nippon Electric Co., Ltd.* Tokyo, Japan

(Continued from page 83A)

nucleus of large-scale, custom-designed governmental data processing systems.

Earlier, he was supervisor of planning and domestic support for the company's data processing portion of the Air Force's Ballistic Missile Early Warning System (BMEWS).

Prior to joining Sylvania, he was affiliated with Gabriel Electronics Company, General Electric Company, and the Boston Naval Shipyard. He was a staff member at the Lincoln Laboratories of Massachusetts Institute of Technology, Lexington, following World War II service with the U. S. Army Signal Corps.

❖

Univac, St. Paul, Minn., has assigned a former Air Force research and development officer to its new computer engineering center in Cocoa Beach, Fla.

R. L. Howell

He is **Robert L. Howell** (M'59), whose responsibilities as a Univac systems design engineer will be "in the area of data handling systems for missile and space vehicle test ranges," according to Dr. A. A. Cohen, Engineering Director of System Planning for the St. Paul Univac Military Department.

The new office is in addition to the company's permanent staff of engineers and technicians assigned to nearby Cape Canaveral, where the Univac "Athena" computer is employed to guide the Air Force's Titan ICBM and the National Aeronautics and Space Administration's various satellites (Tiros, Echo and Explorer X).

A native of Clinton, Mo., Mr. Howell spent three years in the Far East as an armament systems engineer for the Air Force, before his assignment to the AF missile test center, Patrick AFB, Fla.

He was graduated from the U. S. Naval Academy, Annapolis, Md., in 1952, and from the Massachusetts Institute of Technology, Cambridge, in 1957. Also, he is a member of the American Rocket Society.

❖

WacLine, Inc., has announced the election to its Board of Directors of **Dr. Howard H. Aiken** (SM'56–F'60), Director of Harvard Computation Laboratory and Professor of Applied Mathematics at Harvard University, Cambridge, Mass.

In addition to serving as Director and Consultant to WacLine, he is also Chairman of the Board for Systems Research Laboratories, Inc., of Dayton, Ohio.

As consultant, scientist and educator in the field of automatic computation techniques, he has earned recognition and honors from many American and foreign military and civilian agencies and societies.

❖

(Continued on page 86A)

FINE WIRE
for
- Semiconductors
- Resistors
- Potentiometers
- Thermocouples
- Electronic Tubes
- Other Electronic Applications

in
precious, base, exotic and special metals — bare or insulated

Custom Melting, Complete Redrawing, Strand and Vacuum Annealing Services for fine wire processing to customers' specifications.

WRITE for valuable brochure containing fine wire compositions, pertinent properties and applications.

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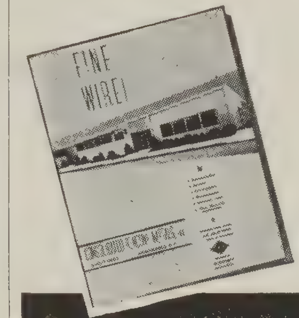
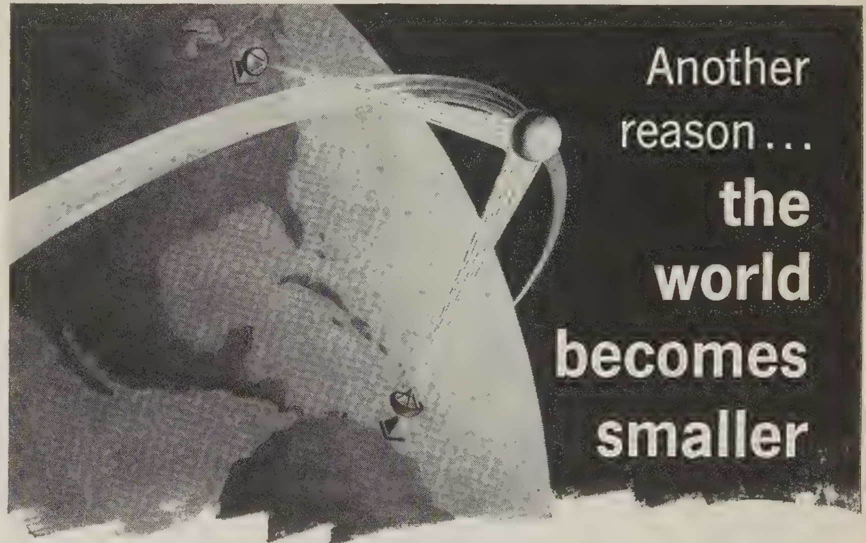
CONSOLIDATED REACTIVE METALS, inc.
115 Hoyt Avenue — Mamaroneck, N. Y. — OWens 8-2300




Another reason . . . the world becomes smaller

An experimental satellite communication relay being designed and engineered under cognizance of Rome Air Development Center will transmit voice and teletype 2000 miles through space via a passive orbiting satellite. Stations will be at Floyd, N.Y. and Trinidad.

Page COMMUNICATIONS ENGINEERS, INC.
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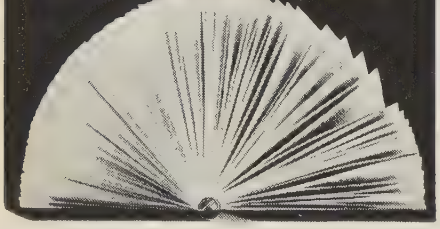
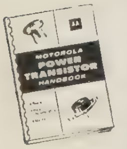
MOTOROLA

VALUABLE
HANDBOOKS
for
CIRCUIT
ENGINEERS



Complete your reference bookshelf with these liberally-illustrated technical handbooks

POWER TRANSISTOR HANDBOOK



A 200 page manual with 9 chapters covering: Semiconductor electronics, transistor characteristics, power amplifiers, switching applications, ignition systems, special circuits, power supplies, testing and specifications. Written by Motorola's Applications Engineering Department. Price $2.00.

ZENER/RECTIFIER HANDBOOK

A new 185 page guide to basic theory, design characteristics and applications of zener diodes and rectifiers. The second edition of the popular zener handbook first published in 1959. Price $2.00.

ORDER TODAY—You can obtain these handbooks from your local Motorola Semiconductor distributor or by sending $2 (check or money order) for each book to Motorola Semiconductor Products Inc., 5005 East McDowell Road, Phoenix 10, Arizona. Please specify handbook desired. No purchase orders, please.

MOTOROLA
Semiconductor Products Inc.
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IRE People

(Continued from page 85A)

Gerald E. Hughes (S'52–A'43–M'58) has joined the Micromodular Components Division of Ling-Temco Electronics, Inc., as head of applications engineering. This division of Ling-Temco is engaged in the design, fabrication, and testing of highly compact miniature circuit modules.

G. E. Hughes

He is well known for his work in the field of semiconductor technology and semiconductor device applications. Prior to joining Micromodular, he was employed by Rheem Semiconductor Corporation as a member of the technical staff for diode and rectifier applications. He also has been affiliated in similar capacities with Hughes Aircraft Company and Raytheon Manufacturing Company.

Mr. Hughes has been active in applications engineering and applied electronics since receiving the B.S.E.E. degree from Case Institute of Technology, Cleveland, Ohio, in 1952, with honors. His major work has been in applications of semiconductor diode and rectifier technology, industrial controls, and computing circuits. He has written several articles on semiconductors, circuits, thermal properties, and magnetic amplifiers.

❖

Dr. George Truman Hunter (M'46) of International Business Machines Corporation recently received the honorary degree of Doctor of Science from the University of Tampa, Tampa, Fla. He is advanced management control systems manager for IBM's Federal Systems Division.

G. T. Hunter

He was awarded the honorary degree by Tampa University's President D. M. Delo during graduation ceremonies at the 30-year-old school on June 5, 1961. He is an alumnus of the university, having been graduated there with the B.S. degree in mathematics in 1939. In 1941, he received the Master of Science degree from the University of Florida and the Ph.D. degree in experimental nuclear physics from the University of Wisconsin, Madison, in 1949.

Dr. Hunter joined IBM in 1950 as an applied science field representative. During the 1960 presidential campaign, he was manager of election processing activities for IBM. He trained a team of Columbia Broadcasting System news correspondents and IBM mathematicians in the use of powerful data processing systems employed in tabulating and analyzing the vote on election night.

❖

Dr. Eugene C. LaVier (A'46–M'55), formerly a U. S. Air Force colonel, has been named Chief Physicist of the National Company, Inc., Malden, Mass.

E. C. LaVier

A World War II squadron commander, he served during the early post-war period at Wright Field, Scott Field, and Tokyo. In 1953 he received the Ph.D. degree from The Johns Hopkins University, Baltimore, Md.

From 1953 until he joined National this year, he engaged in Air Force research on subjects such as high altitude nuclear testing, ICBM defense, space exploration, and rocket and balloon research. In 1959 he was appointed chief of military analysis teams of the Office of Plans, ARDC, and as such, organized and effected a new analysis program and approach for evaluation of future systems.

Dr. LaVier is a member of Sigma Xi and the American Physical Society.

❖

Election of **Eugene F. Peterson** (M'54) as Vice President of Marketing, Consumer and Industrial Products, has been announced by H. S. Geneen, President of International Telephone and Telegraph Corporation.

Associated with General Electric Company for 27 years, he assumes his new post at ITT after serving as Manager of the Consumer Goods Export Department of International General Electric Company Division for the past six years. In this capacity, he acted as Marketing Executive for electronic components and light industrial products as well as consumer products exported throughout the world, with the exception of Canada.

Previously he had acted in a number of executive capacities for GE, including marketing of consumer goods in the United States, product and design engineering and manufacture of electronic components.

As Manager of Marketing for the radio and television department of the electronics division, he was responsible for all United States marketing of radio, television and high fidelity products.

Earlier he served as Manager (marketing) of the tube department of the electronics division, directing sales to original equipment and replacement markets of all electronic tubes and associated products.

He is a graduate of General Electric's advanced courses in both engineering and management.

A native of Waverly, Kan., he holds the Master of Science and Bachelor of Science degrees from Kansas State University.

Mr. Peterson is a member of the American Institute of Electrical Engineers.

❖

ANOTHER
ADVANCED
MICROWAVE
TUBE
DEVELOPMENT
RAYTHEON
QKW928
MADE IN U.S.A.
SERIAL NO
139
138
137

COMPACT C-BAND TWT, QKW 928, utilizes PPM focusing for lightweight construction. VSWR is 1.1 over any 50 Mc channel. Tube is also available with coaxial fittings for full octave (4-8 kMc) coverage.

Raytheon introduces low-cost 12-watt TWT for long-life microwave relay operation

Rugged all metal-ceramic tube for 5,925 to 7,125 Mc range designed for power amplifier service in unattended stations.

The QKW 928 offers a combination of advantages never before available in a traveling wave tube for communications applications.

This 12-watt tube's periodic permanent magnet focusing permits a new, simpler, more compact construction that assures long life and permits a lower cost. The new design reduces external magnetic fields so that two tubes can be mounted in close proximity to each other.

Write today for detailed technical data or application service to Microwave and Power Tube Division, Raytheon Company, Waltham 54, Massachusetts. In Canada: Waterloo, Ontario.

QKW 928 TYPICAL OPERATING CHARACTERISTICS

Frequency Range	5,925-7,125 Mc
Power Output (saturated)	12 Watts minimum
Small Signal Gain	36 db
Helix Voltage	2,600 Vdc
Collector Voltage	2,600 Vdc*
Anode Voltage	2,650 Vdc
Filament Voltage	6.3 Volts

*Can be depressed to 1,400 volts for improved efficiency.

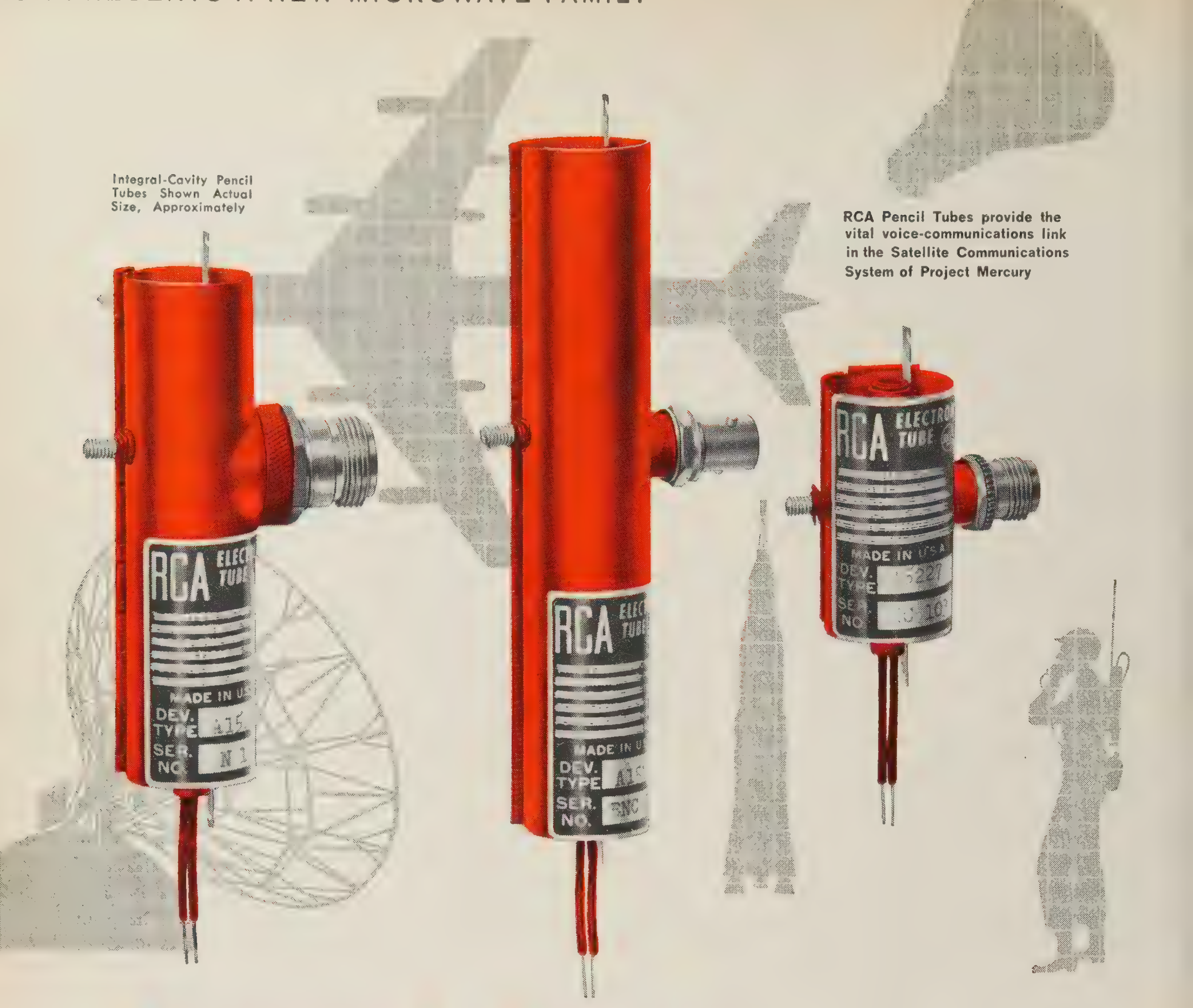
RAYTHEON

RAYTHEON COMPANY

MICROWAVE AND POWER TUBE DIVISION

See us at WESCON—Booth 3410-3412

RCA PRESENTS A NEW MICROWAVE FAMILY



Integral-Cavity Pencil Tubes Shown Actual Size, Approximately

RCA Pencil Tubes provide the vital voice-communications link in the Satellite Communications System of Project Mercury

Integral-Cavity

PENCIL-TUBE OSCILLATORS

- From 900-3400 Mc
- Low-cost
- Includes RF Circuitry
- Compact

OVERALL RF PERFORMANCE ASSURED

ow, RCA offers the recognized performance-
vantages of the famous coaxial pencil tube
. in a design which combines the pencil
pe with a mechanically-tuned cavity—to
oduce a single-unit, compact, low-cost
crowave oscillator.
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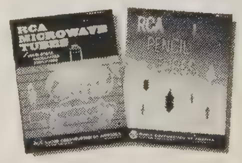

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August, 1961
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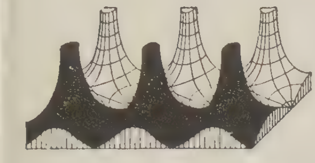
Poles and Zeros



WESCON 1961. This month (August 22–25) the West Coast puts on its "Big Show" for the electronics profession, second only in importance to the IRE International Convention. It is anticipated that 35,000 persons will be present. Each of the forty technical sessions will be comprised of three papers with a panel of authorities who will provide a critique of each. There will be 1180 exhibits in the WESCON show.

The emphasis of this year's program is on the field of radio/radar astronomy. It fits well the coincidence of the convention of the International Astronomical Union, in Berkeley, the dates of which overlap those of WESCON, in San Francisco. The over-all program places emphasis on masers, lasers, and parametric amplifiers related to astronomical programs and to quantum electronics. A joint session featuring speakers from IAU is scheduled.

The IRE WESCON Convention Record, which was initiated in 1957, will not be published this year. WESCON management, after very careful consideration, decided that the abandonment of the Record would release more papers for later publication in the Proceedings and the Transactions of IRE. They feel that this new policy has attracted more high-quality papers since the authors have greater freedom to seek publication in the journal of their choice. The Managing Editor, in cooperation with WESCON, has issued information to all WESCON authors concerning the submission of their WESCON papers to IRE journals. This change in the publication policy of WESCON holds no implication for the IRE International Convention Record; its publication will continue.

For the fifth year WESCON will feature the Future Engineers Show. This outstanding student affair should be a must on the schedule of every attendee at WESCON. Youngsters from high schools throughout the West (including Alaska and Hawaii) gather for a "junior WESCON." They exhibit their own works, have their own technical sessions, and compete for scholarship awards. The forty participants are chosen from regional and area science fairs by local IRE committees. The student exhibits are judged by leaders in the electronics field based on the demonstration, presentation, and content of their displays. The Future Engineers Show, conceived as a service to students, will again this year open the eyes and attract the ears of the "older engineers" attending WESCON.

Poles and Zeros salutes the WESCON Board, Albert J. Morris, O. H. Brown, John V. N. Granger, Calvin K. Townsend, Bruce S. Angwin, Donald C. Duncan, Edward C. Bertolet, and S. H. Bellue. The detailed program, for which they, and nearly 300 Bay Area electronics men and women deserve congratulations, will be found in the IRE News and Notes section of this issue.

Information Retrieval. Poles and Zeros, in October, 1960, discussed the growth of engineering and scientific publication to point up the increasing "problem of too little time for too much to read." Comment was made in that note concerning the helpfulness of various indexing, abstracting, and reviewing services. Although no solution to this complex problem has yet been brought forth it is satisfying to be able to report an increase in IRE services in the form of abstracting and reviewing.

A growing number of the IRE Transactions are publishing abstracts or literature review sections. For example, PGANE published abstracts of the *Journal of the Institute of Navigation* (London); PGCT reviews current literature; PGEC provides abstracts of current computer literature and reviews of books and papers in the computer field; PGEWS publishes book reviews; PGIT gives both abstracts and book reviews; and PGBME publishes abstracts. These Transactions are to be congratulated on this extra service to IRE and Professional Group members.

This service, supplementing as it does the Abstracts and References section and the Book Review section of the Proceedings, is only one phase of the contribution to the solution of the literature problem being made by the Transactions. One cannot ignore the significance of the publication of bibliographies as a literature aid. An outstanding example is the "Bibliography on Medical Electronics," compiled by the Medical Electronics Center of the Rockefeller Institute and published by the Professional Group on Bio-Medical Electronics. This particular bibliography and its two annual supplements cover some 7,600 references in that field.

Not to belabor, but to emphasize, the importance of contributions of this type one may note that both sales figures for the electronics industry and IRE membership have tripled in size in the last decade. Publication volume has correspondingly increased. IRE, for example, published approximately 200 letters and papers in one journal in 1950. In 1960 it published approximately 2,000 items in 32 publications.

It is to be hoped that, pending a unique and radical solution to the problem, additional Transactions will emulate the example of those listed above.

Career Brochure. Poles and Zeros reported, in September, 1960, the issuance of the brochure "Electronics—Career for the Future" as a result of the work and energy of the Cedar Rapids Section. The brochure was so well received that the original printing has been exhausted. It is a pleasure to report that a new printing of a revised brochure will be available this fall through the cooperation of the Electronic Industries Association. Distribution is planned to 28,000 high schools throughout the country.—F. H., Jr.

A. B. Giordano

Director, 1961–1962

Anthony B. Giordano (SM'46–F'58) was born on February 1, 1915, in New York, N. Y. He attended the Polytechnic Institute of Brooklyn, Brooklyn, N. Y., and received the following degrees from that institution: the B.E.E. in 1937, the M.E.E. in 1939, and the D.E.E. in 1946. Also, he was honored with a Certificate of Distinction in 1957 for contributions to education and research.

He joined the academic staff of the Polytechnic Institute of Brooklyn in 1939 as Instructor of Electrical Engineering, became Assistant Professor in 1945, and, in 1952, as Associate Professor, he administered the graduate program in electrical engineering, and launched and coordinated the Polytechnic Graduate Study Program in Mineola, L. I. He was made Professor in 1953, Associate Dean in 1957, and Dean of the Graduate School in 1960, as well as Director of Special Studies.

During World War II he devoted part of his effort to microwave research. As a member of Dr. Ernst Weber's original research team, he assisted in the development of the first microwave precision attenuator. The group was reorganized as the Microwave Research Institute, and he directed several research contracts which led to the development of a series of precision waveguide attenuators. He also guided the program on microwave measurements and has authored over twenty-five research reports and articles in microwaves and related fields.

As a member of the New York Section of the IRE, Dr. Giordano was Secretary during 1952–1953, Vice Chairman during 1953–1954, and Chairmen during 1954–1955. He has also participated in the activities of the Long Island Section, the Professional Group on Microwave Theory and Techniques, the Antennas and Waveguide Committee, and the Professional Group on Circuit Theory.

Dr. Giordano holds membership in Eta Kappa Nu, Sigma Xi, Tau Beta Pi, AAAS, ASEE, and AIEE. In the New York Section of the AIEE, he is now a member-at-large of the Executive Committee. He is also a member of the AIEE Committee on Electronic and High Frequency Measurements and Commission 1 of URSI. Through an impetus provided by Dr. McFarlan, he organized during 1958 an Engineering Advisory Committee for the Board of Education of the City of New York to study the high school curriculum in physics.

Scanning the Issue

Antiferroelectric Ceramics with Field-Enforced Transitions: A New Nonlinear Circuit Element (Jaffe, p. 1264)—Any material that exhibits nonlinear characteristics is potentially useful as a circuit element. Indeed, many of the most important devices of the past decade depend on nonlinearity for their operation. The nonlinearity of certain antiferroelectric ceramics has been known for a number of years. An antiferoelectric is characterized by rows of dipoles, with each row polarized in the opposite direction to that of its neighbor. Under special conditions, an applied field will switch alternate rows so that all rows are polarized in the same direction. This antiferroelectric-to-ferroelectric transition produces a double hysteresis loop characteristic which has a linear central region, rather like a tilted integral sign with a loop on each end. As mentioned above, this transition has been observed in certain materials before, but only within a very narrow temperature range in the 200° C region. This effect has therefore remained little more than a marginal scientific curiosity. This paper demonstrates that the transition can now be made to occur over much wider temperature ranges and in a temperature region of much greater practical interest, namely, from −60° C to over 100° C. What was once a scientific curiosity has thus been transformed into a phenomenon which has a promising future in a number of important applications, including nonlinear capacitors, energy storage devices and electromechanical transducers.

Large-Signal Circuit Theory for Negative-Resistance Diodes, in Particular Tunnel Diodes (Schuler and Gärtner, p. 1268)—The complications of analyzing a device that is nonlinear can usually be circumvented satisfactorily by making approximations which are easier to handle mathematically. The simplification frequently takes the form of substituting an equivalent linear parameter for a nonlinear one. This approach is especially effective in studying small-signal situations. In the case of tunnel diodes, an entire small-signal theory has been satisfactorily developed on this basis by assuming a linear negative resistance. For large-signal applications, however, the entire range of positive and negative resistances of the device are important, and the linear model becomes inaccurate. This paper develops a system of nonlinear differential equations which accurately describes the true large-signal behavior of a tunnel diode, without any of the customary simplifications. The equations are then solved by a computer. The solutions are worked out in detail for large-signal operation of tunnel diodes as oscillators and switches. Since tunnel diode switching applications appear to be a large and important field, these "exact" solutions will be of substantial interest and importance. Equally significant is the fact that the approach presented here can be used to solve a wide class of nonlinear problems.

IRE Standards on Solid-State Devices: Definitions of Terms for Nonlinear Capacitors (p. 1279)—The nonlinearity of semiconductor diode capacitors gives them special characteristics which make them a valued member of the electronic component family. Their nonlinearity also raises a need for special concepts and terminology for describing these special characteristics. This need has now been met by the list of nineteen terms and definitions provided in this standard.

Self-Oscillation in a Transmission Line with a Tunnel Diode (Nagumo and Shimura, p. 1281)—This paper presents an analysis, complete with experimental verification, of the self-oscillations that occur when a transmission line is connected to a negative resistance element, such as a tunnel diode. Both the method of analysis and the particular application discussed make this a paper of more than ordinary interest and importance. The authors have gone back some 25 years in the literature to draw upon a study of the self-oscillations that occur in a violin string. The method of analysis has important application to the broad study of transmission lines with nonlinear terminations, but until now it apparently never received much attention because the original analysis dealt with an acoustic problem and was published in a somewhat inaccessible journal. The specific application discussed here, namely, tunnel diode oscillators that make use of transmission line circuits, is of substantial interests in itself. Now that tunnel diodes capable of operating up to 10 Gc appear feasible, oscillators incorporating simple microwave structures are an attractive prospect. The authors' analysis takes into account the nonlinearities of such a system.

IRE Standards on Solid-State Devices: Measurement of Minority-Carrier Lifetime in Germanium and Silicon by the Method of Photoconductive Decay (p. 1292)—The importance of carrier lifetime to the operation of semiconductor devices is fundamental. Because of the extremely high degree of purity that can be obtained in semiconductor crystals, it has become possible to observe and measure recombination processes in much finer detail than was once possible. Although a number of methods for measuring carrier lifetime have been developed, the one which has gained most widespread use consists of deliberately creating excess carriers in a sample by exposing it to a short burst of optical radiation and then monitoring the voltage drop across the material as the excess carriers recombine. This standard specifies the methods for carrying out this important and basic measurement.

Detection Range Predictions for Pulse Doppler Radar (Meltzer and Thaler, p. 1299)—The subject of this paper, pulse Doppler radar, is a field fast becoming of interest to weapons systems engineers. The study presented here is probably the first serious attempt to set up a mathematical model exclusively tailored to predicting the range of this type of radar. The model allows the variation of most of the important radar parameters and is sufficiently flexible to predict the range of most pulse Doppler radar search systems. Not only is a study of this type much needed today, but it is not unlikely that this paper may become a basic reference.

Low-Level Garnet Limiters (Arams, *et al.*, p. 1308)—There has long been a need for limiters which would protect microwave receivers against overload or burnout, and for power levelers which would eliminate power output variations in microwave power sources. At present, suitable limiters are not available on the market and very little information on these devices is contained in the literature. This paper is representative of what can be done in the area of low-level limiting. The authors describe, and give experimental results for, garnet limiters developed for L and S bands, including such novel types as electronically tunable preselectors, and cavity-type and comb-type limiters. The fact that this is a new and rapidly moving field makes this information especially timely.

Scanning the Transactions appears on page 1348.

Antiferroelectric Ceramics with Field-Enforced Transitions: A New Nonlinear Circuit Element*

BERNARD JAFFE†

Summary—**Ceramic dielectrics capable of field-enforced antiferroelectric-to-ferroelectric transitions from below −60°C to over 100°C have been made. The transition manifests itself by a D/E hysteresis figure with a linear central region and loops showing saturation on either end. Previously studied materials have exhibited this phenomenon only in a very limited temperature range. Conditions for obtaining the effect over a wide temperature range are: 1) a polymorphic inversion from ferroelectric to antiferroelectric with ascending temperature, and 2) a relatively high-peak dielectric constant at the antiferroelectric-paraelectric transition temperatures. Nonlinear capacitance, usefulness for capacitive energy storage, and novel transducer properties are described.**

INTRODUCTION

THIS PAPER describes ceramic dielectrics that have a field-enforced antiferroelectric-to-ferroelectric transition. Examples of this phenomenon have been known for some time, but have been restricted to very limited temperature ranges just under a dielectric-constant maximum that varies from one composition to another. Now, however, this range has been extended widely, from below −60°C to over 100° or 125°C. In this form, these ceramics seem to constitute a new class of nonlinear circuit element.

An antiferroelectric is characterized by rows of dipoles, with the dipole moment of adjacent rows equal but antiparallel.[1] This arrangement can be regarded as two interpenetrating sublattices of equal and opposite polarization, with no net spontaneous polarization. We shall use the term "soft" to describe those antiferroelectrics in which an attainable applied field can switch the direction of polarization of the sublattice it opposes. Most antiferroelectric crystalline materials would break down before switching in this way. They would behave as linear, low-loss capacitors.

It is well known that crystal or ceramic $PbZrO_3$ is capable of undergoing such a change for a few centigrade degrees below 230°C, its temperature of maximum dielectric constant. In this field-enforced phase change, the structure changes from a staggered orthorhombic arrangement[2,3] to a polar arrangement, probably rhombohedral,[4] whenever the applied field exceeds a certain threshold value. This manifests itself by a double hysteresis loop with a linear central region and open areas on either end (Fig. 1). It was first described by Shirane, Sawaguchi, and Takagi[5] and has been studied further.[6,7] Similar instances of soft antiferroelectricity with slightly greater temperature range, perhaps 30 centigrade degrees in a region near 200°C, have been described[6,8] for $PbZrO_3$ modified with small amounts of Ti^{+4} or Ba^{+2}. A related phenomenon has been observed by Merz[9] in $BaTiO_3$ just over its Curie temperature. In this case, the linear central region of the hysteresis loop denotes a paraelectric ground state rather than an antiferroelectric one, and the temperature range of this effect is very small.

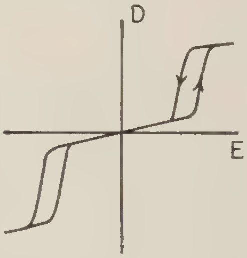


Fig. 1—Hysteresis loop for an antiferroelectric with a field-enforced ferroelectric transition.

METHOD OF ACHIEVING SOFT ANTIFERROELECTRICITY OVER A WIDE TEMPERATURE RANGE

Shirane, Sawaguchi, and Takagi[5] ascribed the anomalous hysteresis loop and the existence of the dielectric-constant maximum in $PbZrO_3$ to a ferroelectric phase, itself unstable, having free energy slightly greater than that of the stable antiferroelectric phase. The energy

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* Received by the IRE, November 1, 1960; revised manuscript received, April 17, 1961.

† Electronic Res. Div., Clevite Corp., Cleveland, Ohio.

[1] C. Kittel, "Theory of antiferroelectric crystals," *Phys. Rev.*, vol. 82, pp. 729–732; June, 1951.

[2] E. Sawaguchi, H. Maniwa and S. Hoshino, "Antiferroelectric structure of lead zirconate," *Phys. Rev.*, vol. 83, p. 1078; September, 1954.

[3] F. Jona, G. Shirane, F. Mazzi and R. Pepinsky, "Neutron diffraction study of antiferroelectric lead zirconate, $PbZrO_3$," *Phys. Rev.*, vol. 105, pp. 849–856; February, 1957.

[4] G. Shirane and S. Hoshino, "X-Ray study of phase transitions in $PbZrO_3$ containing Ba or Sr," *Acta Cryst.*, vol. 7, pp 203–210; February, 1954.

[5] G. Shirane, E. Sawaguchi and Y. Takagi, "Dielectric properties of lead zirconate," *Phys. Rev.*, vol. 84, pp. 476–481; November, 1951.

[6] E. Sawaguchi, "Ferroelectricity versus antiferroelectricity in the solid solutions of $PbZrO_3$ and $PbTiO_3$," *J. Phys. Soc.* (*Japan*), vol. 8, pp. 615–629; September–October, 1953.

[7] A. P. DeBretteville, Jr., "Threshold field and free energy for the antiferroelectric-ferroelectric phase transition in lead zirconate," *Phys. Rev.*, vol. 94, pp. 1125–1128; June, 1954.

[8] G. Shirane, "Ferroelectricity and antiferroelectricity in ceramic $PbZrO_3$ containing Ba or Sr," *Phys. Rev.*, vol. 86, pp. 219–227; April, 1952.

[9] W. J. Merz, "Double hysteresis loop of $BaTiO_3$ at the Curie point," *Phys. Rev.*, vol. 91, pp. 513–517; August, 1953.

gap between the two possible phases governs the threshold field necessary to excite the anomalous hysteresis loop.

To achieve a soft antiferroelectric stable over an extended temperature range, it was desired to have a low and stable threshold field. The ideal way to do this would be to make an antiferroelectric ceramic extremely close in composition to a morphotropic-(composition dependent-temperature independent) phase boundary between antiferroelectric and ferroelectric phases. However, no such boundary is perfectly morphotropic. Accordingly two criteria were adopted. They were: 1) the sequence of change with heating was to be ferroelectric-to-antiferroelectric-to-paraelectric, and 2) the dielectric-constant maximum at the antiferroelectric-to-paraelectric transition was to be as high as possible. This would ensure equal energy between the ferroelectric and antiferroelectric states at the ferroelectric to antiferroelectric inversion temperature and almost equal energy at the antiferroelectric-to-paraelectric inversion temperature. It would also favor reasonably uniform properties within the antiferroelectric range.

The desired sequence of the phase changes is exemplified in Fig. 2, which shows the low-field dielectric constant and loss for a composition that changes from ferroelectric to antiferroelectric at about 90°C. The low losses at temperatures above this are typical of antiferroelectrics, and the loss peak associated with the dielectric-constant maximum in a ferroelectric is clearly absent.

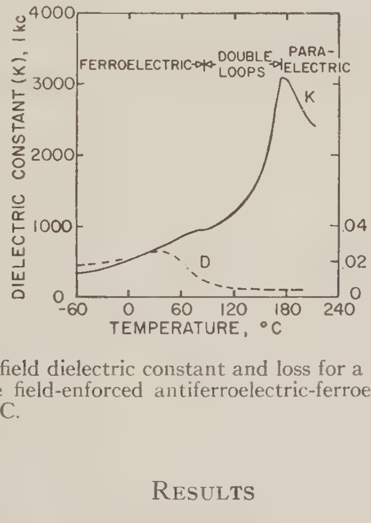

Fig. 2—Low-field dielectric constant and loss for a composition that shows the field-enforced antiferroelectric-ferroelectric transition above 90°C.

RESULTS

Hysteresis Loops at Varying Temperatures

These conditions have been realized in a series of related ceramic compositions that show the anomalous hysteresis loops from temperatures as low as -60°C or lower, to over 100°C. The dielectrics studied are pseudocubic perovskite solid solutions. They are based on antiferroelectric Pb(Zr, Sn)O_3 compositions, which are orthorhombic perovskites, isostructural with $PbZrO_3$ and showing similar superstructure lines in their X-ray pattern.[10] These antiferroelectrics have been modified by compositional additives, so that they show ferroelectricity at low temperatures, as outlined in the preceding section. The type and amount of the additives govern the temperature of the ferroelectric-to-antiferroelectric transition. For most compositions studied, the dielectric-constant maximum, which represents an antiferroelectric-to-paraelectric transition, occurs between 150° and 200°C.

The series of 60-cps hysteresis loops, shown in Fig. 3, for one of these compositions illustrates the results achieved. Somewhere below -50°C the material shown is ferroelectric. Above 125°C as the temperature of the dielectric-constant maximum is approached, the character of the *D-E* loop gradually approaches a closed saturating-type figure (Fig. 3, 128°C). There is no sharply defined upper temperature limit for obtaining the double loop. Its character is entirely subdued when the temperature of the dielectric-constant maximum is reached. The ferroelectric parts of the loop gradually become slimmer (less lossy) with increasing temperature.

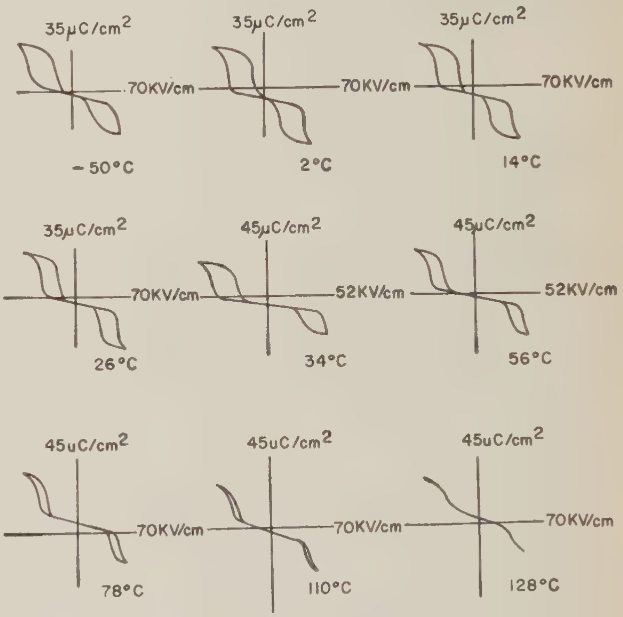

Fig. 3—Hysteresis loops for a composition showing field-enforced transition from below -50°C to above 125°C. Because of the high threshold fields, some were poorly saturated.

Capacitance Nonlinearity

Inasmuch as the slope of the hysteresis loop indicates the differential (dc) capacitance of the sample, it is apparent that this parameter increases sharply as the field passes the threshold for inducing the ferroelectric state.

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[10] B. Jaffe, R. S. Roth and S. Marzullo, "Properties of piezoelectric ceramics in the solid-solution series lead titanate-lead zirconate-lead oxide: tin oxide and lead titanate hafnate," *J. Res. N.B.S.*, vol. 55, pp. 239–254; November, 1955.

It then drops as the loop saturates, and increases again as the field falls through the range where the polarization drops sharply and the antiferroelectric state appears. Thus in each half cycle, we have two intervals of high differential dielectric constant, corresponding to the two steep parts of the loop. Inasmuch as typical values at room temperature are 700 at low field and 5000 for the average (tip-to-tip) value at high fields, it can be seen that the differential value during dipole swtiching is quite high.

In contrast to the behavior of the differential (dc) dielectric constant, the small-field incremental (ac) dielectric constant, measured with a small 1000-cps alternating field superimposed on slowly varying bias, increases slowly with increasing bias through the antiferroelectric range, then drops as the threshold field is exceeded and approaches a saturation value. Because of the hysteresis, it remains low until the bias field falls enough to allow reversion to the antiferroelectric state, then rises to the original value. Typical values of the dielectric constant are 700 to 1000 at low bias and half that at saturation. This behavior is shown diagramatically for soft antiferroelectric and conventional ferroelectric samples in Fig. 4.

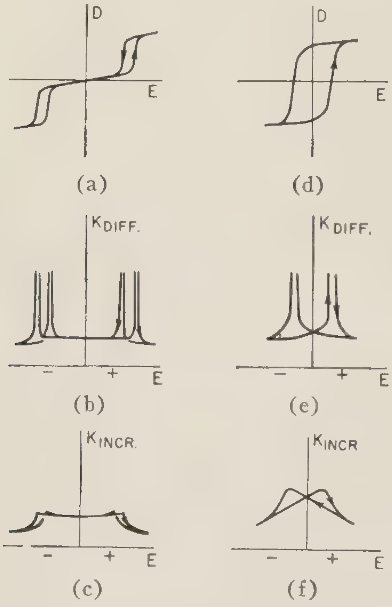
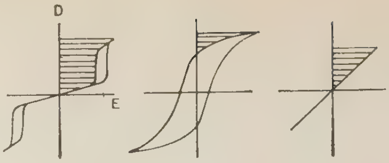


Fig. 4—Hysteresis loop, differential dielectric constant (slope of loop) and incremental dielectric constant (1000-cycle measuring field with slowly-varying bias) for: (a)–(c) a soft antiferroelectric, and (d)–(f) a normal ferroelectric.

Energy Storage

It has been suggested by H. Jaffe of this laboratory that such a dielectric would have advantages as a high-energy-storage capacitor. In Fig. 5, typical *D-E* Lissajous figures for a soft antiferroelectric, a normal ferroelectric, and a linear dielectric are shown. The energy recoverable from each is denoted by the shaded areas. In the ferroelectric, much of the charging energy is absorbed by domain switching, and remains as remanence. It is available only as pyroelectricity or as irreversible piezoelectricity at pressures greater than those used to produce a linear piezoelectric effect. Remanence can be avoided in part by the use of compositional additives that minimize it. Dielectrics of this nature frequently saturate at relatively low fields. Once saturated, an increment of field causes little additional energy storage. Another way of avoiding remanence is to use a ferroelectric in its paraelectric condition, just above the Curie temperature. Here, too, easy saturation is likely to limit the energy storage.



(a) (b) (c)

Fig. 5—Hysteresis figures for (a) a soft antiferroelectric, (b) a normal ferroelectric, and (c) a linear capacitor. The shaded area denotes the discharge energy.

In the linear capacitor, no remanence occurs, but the dielectric constants are generally low. Storage of appreciable charge requires very high field and, consequently, extreme dielectric strength. The soft antiferroelectrics, too, are free of remanence. A particular advantage of the soft antiferroelectrics is the approach of the "energy area" to a square instead of a triangle. This allows, in principle, energy storage exceeding $D \cdot E/2$, and approaching $D \cdot E$. Typical charges stored are about $25\ \mu C/cm^2$ at peak fields of 40 to 50 kv/cm. In the presently explored materials, these fields approach breakdown for thick sections. The working voltages are thus limited because it is necessary to use thin pieces (1 to $1\frac{1}{2}$ mm at present). It is expected that continued work will improve the dielectric strength.

Transducer Properties

It has been suggested by Dr. R. Gerson and demonstrated by C. P. Germano of this laboratory that the onset of field-enforced ferroelectricity is accompanied by large strain effects parallel to the field. These strains are of the order of 4×10^{-4}.

The types of electromechanical effects are shown in Fig. 6. Hard antiferroelectrics show quadratic electrostriction, like all other solids. Ferroelectrics, due to domain switching, give the well-known butterfly loops shown. They can be poled and used at remanence to produce a linear piezoelectric response, like piezoelectric crystals. The soft antiferroelectrics produce the abrupt incremental strain shown in the figure. This constitutes a sort of quasi-electrostriction of large magnitude. Samples biased by a dc- or low-frequency field to a point beyond the threshold field respond as a piezoelectric to small signal fields, especially at mechanical resonance. Thus the bias field can act as a controlling or modulating means. It also seems probable that samples can be

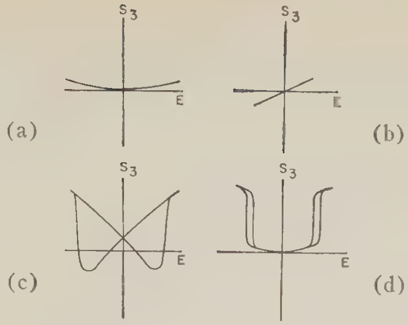


Fig. 6—Strain vs field in (a) electrostriction, (b) piezoelectricity, (c) ferroelectricity, and (d) soft antiferroelectricity.

driven at mechanical resonances by strong signals of half the resonant frequency, but this has not yet been demonstrated.

Improvements Needed

Like other ceramic dielectrics, these soft antiferroelectrics are subject to breakdown at high fields. This factor most strongly limits their utility. Although it is possible to obtain much lower threshold fields by raising the ferroelectric-to-antiferroelectric transition temperature, the lowest threshold field yet found in a composition antiferroelectric down to −60°C is about 40 kv/cm. Although operation at fields of this strength is tolerable in thin specimens, it is undesirable where high voltage applications are desired, such as in energy storage. It is also desirable to have low threshold fields for the nonlinear capacitor and transducer applications. Here, low-voltage operation is usually desired, and although thin specimens can be used, there is a practical minimum to thickness. This indicates two development objectives: increasing the dielectric strength and finding compositions with lower threshold fields. There is hope that both of these can be improved.

Conclusion

Soft antiferroelectrics are those capable of field-enforced transitions to a ferroelectric state at fields below breakdown. They show a characteristic double hysteresis loop with a linear central region and a saturated loop on either end. Previous examples of this phenomenon have had limited temperature range. The effect can be produced over a wider temperature range by 1) a polymorphic inversion from ferroelectric-to-antiferroelectric-to-paraelectric states with increasing temperature, and 2) a relatively high dielectric-constant maximum at the antiferroelectric-to-paraelectric inversion temperature. An example of such a dielectric is shown, with the desired type of behavior occurring through the temperature range of below −50° to above 125°C. With fields passing the threshold for the field-enforced transition, the differential (dc) capacitance increases greatly, while the incremental (ac) capacitance drops. Simultaneously, strain of the order of 10^{-4} occurs. The shape of the hysteresis loop is favorable for energy storage. Present utility is limited by dielectric strength.

Acknowledgment

In addition to the contributions of my colleagues mentioned in the text, the help and interest of D. Berlincourt and H. H. A. Krueger, and the careful work of R. Wolfe, Miss M. E. Christopher, F. Brunarski and B. Kost are gratefully acknowledged.

Large-Signal Circuit Theory for Negative-Resistance Diodes, in Particular Tunnel Diodes*

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Summary—**The large-signal, high-frequency circuit applications of a tunnel diode as an oscillator and as a monostable and bistable switch have been analyzed quantitatively, without any of the customary simplifications, by solving on a computer the system of nonlinear differential equations which describe the diode and the external circuitry. Frequency, amplitude, distortion and switching times are calculated with high accuracy as functions of operating point and circuit inductance. The results are in very good agreement with actual measurements.**

INTRODUCTION

MOST circuit theory is based on a linearization of the characteristic of the component used. Nonlinear theories usually depend either on relatively simple analytical approximations of the component characteristics such as the exponential or square-law characteristics of diodes used in mixing and frequency conversion, etc., or on a piece-wise linearization of the complicated component characteristic, which is commonly used in negative-resistance circuit theory. In practically no case do these approaches yield quantitative answers to such typical large-signal nonlinear problems as the determination of output waveform, harmonic content, large-signal switching time, etc., although they usually give satisfactory results in an analysis of stability.[1,2]

In this paper we propose to develop a large-signal circuit theory for negative-resistance diodes in which the device and its external circuit are characterized by a system of accurate nonlinear differential equations and the solutions are obtained by an electronic computer. This approach is very general and can be applied to any nonlinear electronic device. It is worked out below in detail to describe the large-signal operation of tunnel diodes as oscillators and switches.

CHARACTERIZATION OF THE TUNNEL DIODE

For small-signal applications the tunnel diode is satisfactorily characterized by its differential negative resistance $(-R)$, its junction capacitance C_j and series bulk resistance r_s, as shown in Fig. 1(a).[3] This equivalent circuit has been employed successfully to derive expressions for the gain, bandwidth, etc., of small-signal tunnel-diode amplifiers, and the cutoff frequency of tunnel-diode oscillators. Linear fourpole equations for the tunnel diode based on this circuit[4] can be used to formulate the entire small-signal circuit theory for tunnel diodes. It is obvious, however, that this small-signal equivalent circuit cannot be used to accurately describe large-signal applications in which the entire range of positive and negative resistances is important, such as large-signal oscillators and monostable and bistable switches. Therefore, the equivalent circuit of Fig. 1(a) was extended. The proposed large-signal equivalent circuit used in this paper consists of a nonlinear current source in parallel to the capacitance of the *p-n* junction and a series resistance presenting the bulk and contact resistances. This circuit is shown in Fig. 1(b). The tunnel phenomenon is very fast and no delay effects are included in the current generator. The junction capacitance represents all the storage mechanisms in this device. The junction capacitance has been chosen to be constant over the whole voltage range. This is a slight simplification because the capacitance of a forward-biased junction depends on the voltage across it. The simplification seems to be justified because the capacitance is much less dependent on the voltage than the junction current in the voltage range of interest, so that the voltage dependence of the capacitance introduces negligible corrections in the cases discussed in this paper.

The generalization of the approach used here for a voltage-dependent junction capacitance is obvious. The series bulk resistance is also considered constant in our analysis because the current densities during operation are not high enough to cause high-injection resistance modulation. Again, this assumption could be easily removed if the need became apparent.

The equations describing the large-signal operation of the tunnel diode are therefore:

$$v_D = v_J + i_D r_s \tag{1}$$

$$i_D = C_j \frac{dv_J}{dt} + i(v_J). \tag{2}$$

Fig. 2 shows the measured dc characteristics $i(v_D)$ of the tunnel diode used in the analysis and the experiments. Because of the small series resistance of $r_s = 0.3$ ohm, in

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† CBS Labs., Stamford, Conn.

[1] W. J. Cunningham, "Introduction to Nonlinear Analysis," McGraw-Hill Book Co., Inc., New York, N. Y., ch. 5; 1958.

[2] B. G. Farley, "Dynamics of transistor negative-resistance circuits," PROC. IRE, vol. 40, pp. 1497–1507; November, 1952.

[3] H. S. Sommers, Jr., "Tunnel diodes as high-frequency devices," PROC. IRE, vol. 47, pp. 1201–1206; July, 1959.

[4] W. W. Gärtner, "Tunneldioden," Elektronische Rundschau, Berlin, Germany, vol. 14, pp. 265–271; July, 1960.

this case, the device voltage v_D and the junction voltage v_J are practically the same for dc. The junction capacitance of 390 pf was measured at the valley point.

OSCILLATOR

Analyzing the oscillations of negative-resistance elements has long been an electrical engineering problem[1,2] and while it is rather simple to show that a negative resistance with the approximate load will oscillate, it is quite an involved problem to find the exact output waveform of the oscillator. To solve the problem analytically, the characteristic of the negative element must be oversimplified and the results are only in qualitative agreement with the exact solutions. Graphical methods are tedious when accurate solutions must be obtained. Both methods are useful only when a small number of nonlinearities appear in the circuit. The approach used here to obtain an exact answer to the tunnel-diode oscillator problem was to find on a digital computer the exact stable solution to the set of exact nonlinear differential equations which describe the device and circuit.

External Circuits

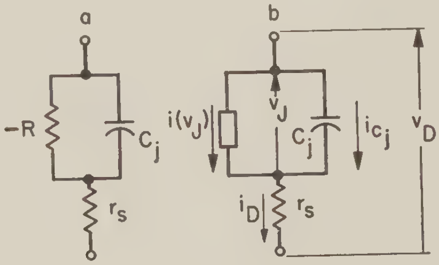
Since the device itself has an internal capacitance, it is enough to add an external inductance to excite oscillations when the diode is biased in the negative-resistance region. This simplest oscillator circuit, shown in Fig. 3, will be used to illustrate the proposed approach, generalizations to more complicated external circuitry being obvious. The external inductance has been assumed lossless, and any losses can be included simply in the series bulk resistance of the device r_s. We are now in a position to write down the entire set of differential equations which describe the oscillator operation:

$$\left.\begin{aligned} v_D &= v_J + i_D \cdot r_s & (1)\\ i_D &= C_j \frac{dv_J}{dt} + i(v_J) & (2)\end{aligned}\right\}\text{ device}$$

$$v_L = L\frac{di_L}{dt}\text{ external circuit} \qquad (3)$$

$$\left.\begin{aligned} v_D &= v_0 + v_L & (4)\\ i_L &= -i_D & (5)\end{aligned}\right\}\begin{array}{l}\text{relations connecting device}\\ \text{and external circuit.}\end{array}$$

The only nonlinearity entering this set of equations is the relation between junction current and voltage in (2). This function has been obtained by measurement and has been plotted in Fig. 2.



(a) (b)

Fig. 1—(a) Small-signal and (b) large-signal equivalent circuits for tunnel diodes.

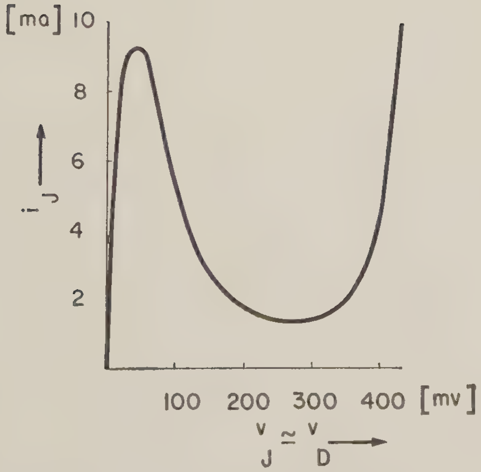


Fig. 2—Measured junction-current vs junction-voltage characteristic of tunnel diode (germanium) used for theory and experiments.

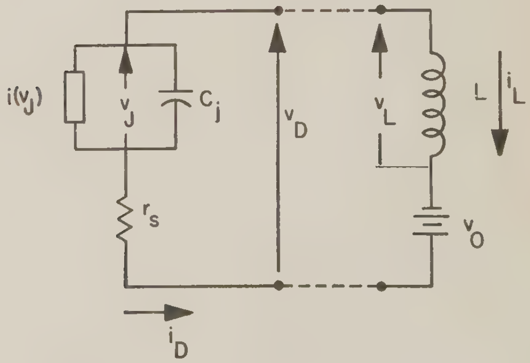


Fig. 3—Tunnel-diode oscillator circuit.

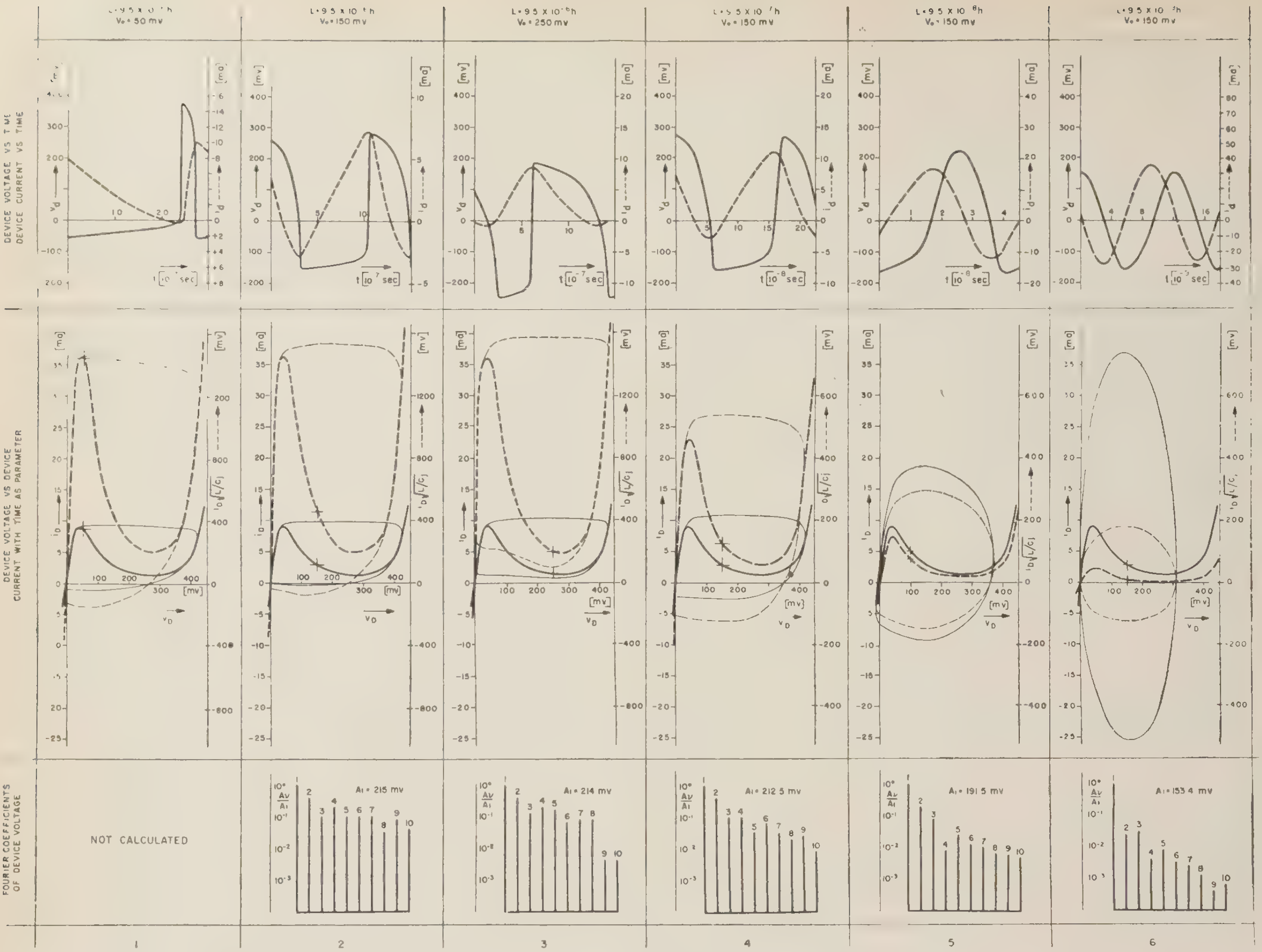


Fig. 4—Upper row: ac device voltage v_d (solid lines) and device current i_d (dashed lines) as functions of time t for six combinations of operating point and external circuit inductance.

Middle row: dc device characteristic (heavy lines) and limit cycle, *i.e.*, instantaneous device current vs device voltage (light lines) for six cases depicted in the upper row. The solid curves compare the limit cycles in the various cases plotted to identical scales. The dashed lines give the same information with each graph normalized so that the limit cycle for a strictly sinusoidal oscillation would appear as a circle.

Lower row: The first ten Fourier coefficients of the device voltage plotted on a logarithmic scale.

Solution

This system of differential equations has been solved on a digital computer with starting values chosen in such a way as to get the stable solution within a small number of periods. Fig. 4 shows some of the oscillation patterns achieved for different operating points and external inductances. The first row of graphs represents the ac components of the device current i_d, and of the device voltage v_d, with the bias point as the origin. The second row shows the device characteristic (heavy) and the limit cycle (light) of the oscillation plotted in the i_D-v_D plane (solid) and in the transformed $(i_D\sqrt{L/C_j})$-v_D plane (dashed). The latter transformation has been chosen because in this plane the limit cycle for a sinusoidal oscillation will appear as a circle and any deviation from the circular pattern indicates harmonic content. The third row shows the Fourier analysis of the device-voltage v_d.

The photographs of oscilloscope traces given in Fig. 5 were obtained from an actual circuit using a diode with the characteristic of Fig. 2 and employing the operating points and external inductance given in the first three columns of Fig. 4. One observes excellent agreement with the theoretical predictions.

Various qualitative features of the output waveform and the limit cycle may be illustrated by Fig. 4. When the external inductance L is rather large as in the first three columns of Fig. 4, the limit cycle (second row in Fig. 4) consists of the positive branches of the dc-device characteristic and almost straight lines through the peak and valley points, parallel to the current axis. These parallel lines correspond to very rapid changes in device voltage. Whereas this limit cycle pattern is relatively independent of the operating point, one observes that the latter has a pronounced influence on the output waveform (period, amplitude, and harmonic con-

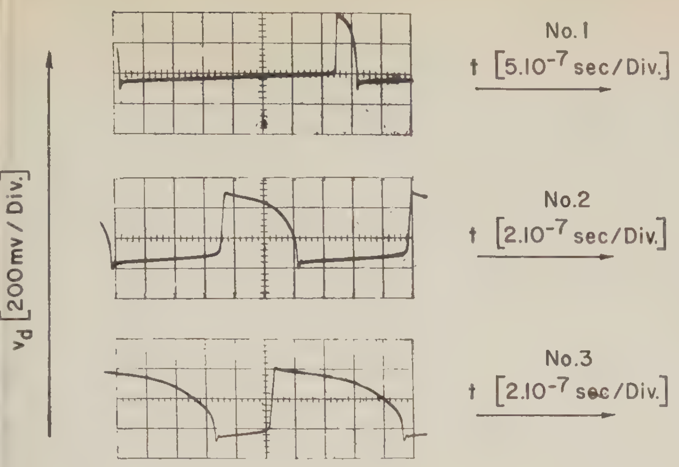


Fig. 5—Photographs of oscilloscope traces showing device voltage vs time obtained in the circuit of Fig. 3 using a diode with the characteristic of Fig. 2. Operating points and external circuit inductance are as follows:

Curve No.	$V_0[m_v]$	$L[h]$
1	50	9.5×10^{-6}
2	150	9.5×10^{-6}
3	250	9.5×10^{-6}

tent). This applies in particular, also, to the dc component of the output current which modifies the assumed operating point. For small bias voltages the dc component of the device current is negative; for large bias voltages it is positive.

The following table gives this dc component for the six cases shown in Fig. 4:

Column in Fig. 4	1	2	3	4	5	6
DC Component of Output Current in ma	−3.70	2.34	3.24	3.96	2.66	1.80

Incidentally, the output voltage across the device has no dc component because of (3) and (4). This shifting of the operating point for oscillating tunnel diodes is a well-known fact and can be observed frequently on oscilloscope traces displaying the characteristic of the tunnel diode.[5] This shift in bias current depends also on the external inductance, as can be seen in the last three columns of Fig. 4, where for the same bias voltage the external inductance has been decreased. The oscillation becomes more and more sinusoidal, the smaller the inductance. This is in keeping with the observation that for L approaching a limiting value $L_{\min}$ (see next section) the limit cycle in the $(i_D\sqrt{L/C_j})$-v_D plane becomes a circle with decreasing radius. The Fourier coefficients of the higher harmonics also decrease with decreasing inductance.

Analytical Approximation

While it is impossible to give an exact analytical solution for the general tunnel diode oscillator, one may obtain a certain amount of qualitative information when the device characteristic is replaced by a simple three-order polynomial. Under this assumption one may calculate how the amplitude of oscillation changes with external inductance (or frequency) and how much the frequency of oscillation differs from the pure sine-wave frequency, calculated for the LC-resonant tank circuit.

Combining (1) through (5) one obtains the following ordinary differential equation for the junction voltage v_J.

$$LC_j\frac{d^2v_J}{dt^2}+\left(r_sC_j+L\frac{di}{dv_J}\right)\frac{dv_J}{dt}+r_si_J(v_J)+v_J-v_0=0. \quad (6)$$

Separating dc and ac voltages,

$$v_J=v_j(t)+v_0 \quad (7)$$

leads to an equation for the ac junction voltage only:

$$LC_j\frac{d^2v_j}{dt^2}+\left(r_sC_j+L\frac{di}{dv_j}\right)\frac{dv_j}{dt}+r_si_j(v_j)+v_j=0 \quad (8)$$

where

$$i_j(v_j)=i_J(v_j+v_0). \quad (9)$$

For the functional dependence of i_j on v_j we now assume a simple third-order polynomial of the form

$$i_j=(g/v_0^2)v_j(v_j^2-v_0^2). \quad (10)$$

Eq. (10) has been plotted in Fig. 6 explaining the meaning of the parameters g and v_0. With (10), (8) can be transformed into

$$\frac{d^2v}{d\tau^2}+\nu(v^2-1)\frac{dv}{d\tau}+v\left\{1-gr_s+\frac{r_sv^2}{3}\left(g-r_s\frac{C_j}{L}\right)\right\}=0 \quad (11)$$

where

$$v=\frac{v_j}{v_0}\sqrt{\frac{3Lg}{Lg-r_sC_j}} \quad (12)$$

$$\tau=\frac{t}{\sqrt{LC_j}} \quad (13)$$

and

$$\nu=\sqrt{\frac{L}{C_j}}\left(g-r_s\frac{C_j}{L}\right). \quad (14)$$

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[5] R. Trambarulo and C. A. Burrus, "Esaki diode oscillators from 3 to 40 kMc, Proc. IRE, vol. 48, pp. 1776–1777; October, 1960.

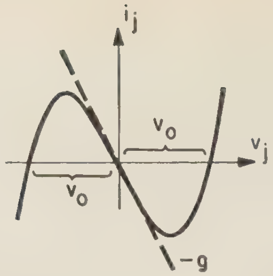

Fig. 6—Symmetrical dc characteristic used for the analysis of tunnel-diode oscillator.

With the device characteristics fixed, the only free parameter in (11) is the external inductance L. One may now ask how the external inductance affects the amplitude and frequency of oscillation. From (12) one concludes that there exists a minimum value for L,

$$L_{\min} = \frac{r_s C_j}{g} \tag{15}$$

where $v_j = 0$.

For values of L close to this minimum value $L_{\min}$, (11) reduces to the equation of a sine wave oscillation:

$$\frac{d^2 v}{d\tau^2} + v(1 - gr_s) = 0. \tag{16}$$

If τ in (16) is replaced by t according to (13), the frequency of this sine wave oscillation can be calculated to be

$$f = \frac{\sqrt{1 - gr_s}}{2\pi\sqrt{LC_j}}. \tag{17}$$

Taking into consideration that L can be replaced by $L_{\min}$ according to (15), we obtain the well-known maximum cutoff frequency ($f_{\max}$) of a tunnel-diode oscillator:

$$f_{\max} = \frac{1}{2\pi C_j}\sqrt{\frac{g(1 - r_s g)}{r_s}}. \tag{18}$$

For inductance values $L > L_{\min}$, one must go back to the exact equation (11). Assuming that r_s is zero, one finds

$$\frac{d^2 v}{d\tau^2} + \nu(v^2 - 1)\frac{dv}{d\tau} + v = 0. \tag{19}$$

This is the well-known van der Pol equation.[1]

The steady-state solution of this equation shows[6] that the period depends strongly on the parameter ν (Fig. 7, solid) but that the steady-state amplitude is practically constant and equal to unity (Fig. 7, dashed). One may use this solution of the van der Pol equation as an approximate solution of (11) provided that $gr_s \ll 1$ because then the correction term

$$gr_s - \frac{r_s v^2}{3}\left(g - r\frac{C_j}{L}\right) \leqq gr_s$$

in (11), will be negligible for all values of L. The condition that $gr_s \ll 1$ is usually well fulfilled in tunnel diodes. For the diode used in our exact solution, gr_s had a value equal to 0.03.

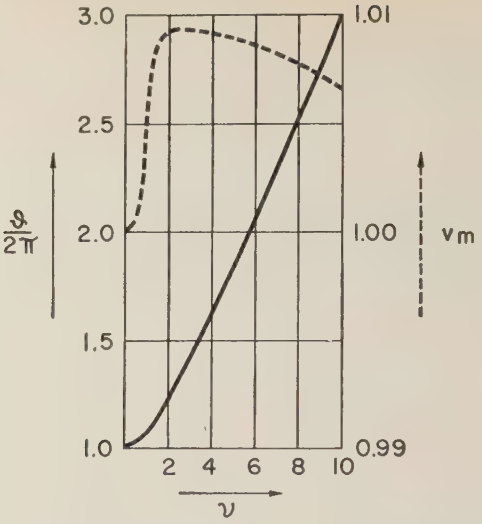

Fig. 7—Period θ (solid) and amplitude v_m (dashed) of the solution of van der Pol equation as function of the parameter ν.

Using (12) and (14), one may therefore transform the solutions of the van der Pol equation in Fig. 7 into solutions of (11) for the steady-state amplitude and frequency of the ac tunnel-diode junction voltage v_j. Since the amplitude of v is approximately unity one finds from (12) the following dependence of the amplitude of v_j on the inductance L:

$$v_{jm} = v_0\sqrt{\frac{Lg - r_s C_j}{3Lg}}. \tag{20}$$

For small values of $gr_s \ll 1$ the amplitude of v_d follows the same dependence, which has been plotted in Fig. 8(a) for various values of g.

The period of oscillation θ depends on ν as shown in Fig. 7 (solid). Analytical expressions have been derived[6] for small ν ($\nu < 2.5$) and large ν ($\nu \geqq 6$):

$$\theta = 2\pi\left(1 + \frac{\nu^2}{16} - \frac{5\nu^4}{3072} + \cdots\right) \quad \text{for } \nu < 2.5 \tag{21}$$

$$\theta = 1.6137\nu + 7.0143\nu^{-1/3} - \frac{22}{9}\frac{\ln \nu}{\nu} + \cdots \text{ for } \nu > 6. \tag{22}$$

Between these ranges, the period can be interpolated. Remembering that the relation of normalized time (τ) to actual time (t) is given by (13), we find the actual period of oscillation (T) from the normalized (θ) by

$$T = \theta\sqrt{LC_j}. \tag{23}$$

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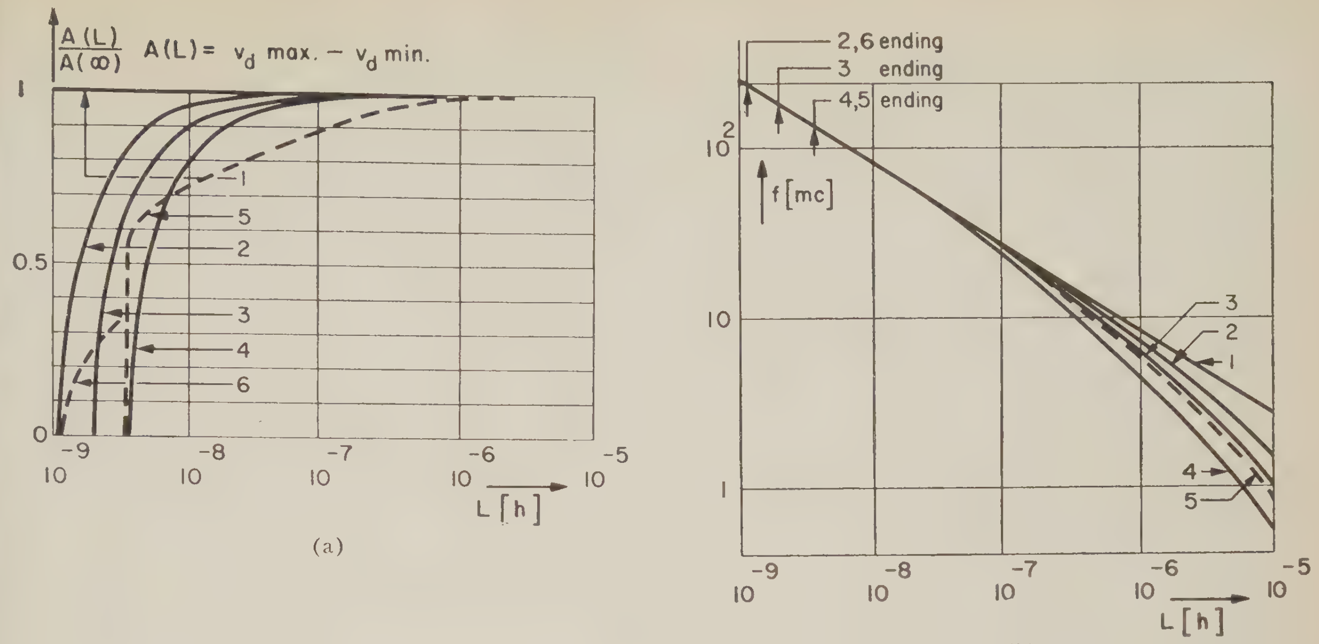
[6] E. Fisher, "The period and amplitude of the van der Pol limit cycle," *J. Appl. Phys.*, vol. 25, pp. 273–274; March, 1954.



(a)

(b)

$C_j = 3.9 \times 10^{-10}$ f

Nº		1	2	3	4			5	6
r_s	ohm	0	0.3	0.3	0.3	r_s	ohm	0.3	0.3
g	mho	0	0.1	0.0326	0.06	V_0	mv	150	75

Analysis Computer

Fig. 8—(a) Normalized amplitude and (b) frequency of tunnel-diode oscillator as a function of circuit inductance L, for analytical approximation (solid line) and for exact computer solution (dashed lines). Parameter: g, r_s, and V_0.

Since θ is a function of ν and ν according to (14) is a function of inductance L, T is a function of L. The frequency f (by definition $1/T$), therefore, is also a function of inductance. This dependence of frequency on inductance L has been plotted in Fig. 8(b) for different values of g. The results of the computer calculations have been plotted in the same figure. For the extreme cases of small and large inductances the following analytical expressions for the frequency can be derived:

$L \approx L_{\min}$:

$$f \approx \left\{ 2\pi\sqrt{LC_j}\left[1 + \frac{1}{16}\,\frac{L}{C_j}\left(g - r_s\frac{C_j}{L}\right)\right]\right\}^{-1} \tag{24}$$

L large:

$$f \approx (1.6137gL)^{-1}. \tag{25}$$

The results obtained from the analytical approximation as compared to those from the exact computer solution show that the frequency of oscillation can be predicted reasonably well except for large values of L. There is, however, a considerable difference between the amplitudes predicted by the approximate treatment and their exact values. An interesting feature which is absent from the analytical approximation occurs in the actual oscillator when it is not biased into the point of steepest negative slope. While for the analytical solution the amplitude of oscillation is decreasing steadily to zero for increasing inductances, the amplitude of the actual oscillator may collapse from a finite value when a certain inductance value is reached. This phenomenon has not been completely explained but the reason seems to be that when the device is not biased at the voltage with the highest negative slope, there exist two limit cycles, a smaller and a bigger one. The small limit cycle is determined mainly by the negative slope at the bias point while the bigger limit cycle is determined by the average negative slope which is higher than the slope in the bias point. The cutoff frequencies of these two limit cycles do not seem to be the same. Thus, for the same inductance, two oscillations with different amplitudes may exist. Whether the large or the small amplitude is excited depends on whether the oscillation is started close to the bias point or reasonably far away. Suitable pulses could switch the circuit from one mode of oscillation to the other.

Fig. 9 shows this situation for the bias point $V_0 = 150$ mv and an inductance value of 3.5×10^{-9} h. While the inner curve 1 is decreasing to zero, there exists a finite

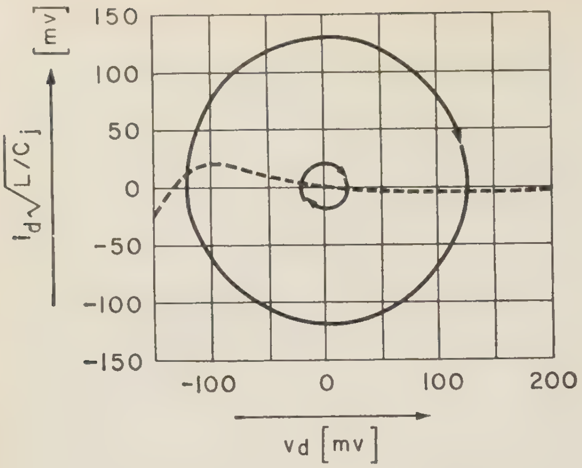


Fig. 9—Two different limit cycles for one inductance value. $V_0=150$ mv, $L=3.5\times10^{-9}$ h.

limit cycle 2 which is stable. When the device is biased at the voltage with the highest negative slope, the amplitude is decreasing steadily to zero with decreasing inductance, as in the analytical case [curve no. 6 in Fig. 8(a)].

MONOSTABLE SWITCH

External Circuit

To use the tunnel diode as a monostable switch, the same circuit as for the oscillator can be used. The only difference between the two cases is that for the monostable switch the device must be biased in the positive-resistance region.

Trigger Pulse

When biased in the positive region the device is stable. To achieve switching action it must be triggered. To avoid an interaction between trigger and switching pulses in our calculations, the trigger pulse has been assumed to be much faster than the resulting switching pulse. Mathematically this is achieved by giving only a starting value in the differential equation.

Solution

Fig. 10 (p. 1276) shows some of the switching plots achieved for different operating points, trigger pulses and external inductances. Column 1 in Fig. 10 shows the trigger output when the device is biased close to the peak point. The inductance has a medium value. For very large inductance values the trace would jump to the opposite positive branch of the device immediately after triggering, in the same way as in the oscillator. For smaller external inductance values (column 2 in Fig. 10) the switching trace changes similar to the oscillator pattern, *i.e.*, the peak current increases and the voltage swing decreases. Column 3 shows the switching plots when the device is biased close to the valley point. Comparing columns 1 and 3, one notices that when the device is biased near the peak point, much smaller trigger pulses suffice to produce large output signals. Therefore, when the monostable switch is used as pulse amplifier, an operating point close to the peak gives highest gains. Column 3 also shows that the output amplitude can be very sensitive to the amplitude of the trigger pulse. A small change in trigger pulse (curves A and B) results in a large change of output waveform.

BISTABLE SWITCH

External Circuit

Fig. 11(a) shows the circuit used to analyze the bistable switch. The only addition to the oscillator and monostable switching circuit is the load resistance r_L.

It follows from this figure that a set of differential equations for the bistable switching circuit can be derived from (1)–(5) if one replaces r_s by r_s+r_L:

$$\frac{dv_J}{dt} = \frac{1}{C_j}\left[i_D - i(v_J)\right] \tag{26a}$$

$$\frac{di_D}{dt} = \frac{1}{L}\left[v_0 - v_J - i_D(r_s + r_L)\right]. \tag{26b}$$

The load resistance and the bias voltage are adjusted to produce three intersections with the device characteristic, as shown in Fig. 11(b). In general, two of the points of intersection (1, 2) are stable and one is unstable (3).

Solution

Fig. 12 shows the forward and backward switching of the bistable circuit for different trigger pulses and inductances. Column 1 illustrates the case where the circuit is triggered from the high-current, low-voltage state (stable point 1) to the low-current, high-voltage state (stable point 2). The circuit will switch to point 2 only when the trigger pulse is larger than a certain critical amplitude (curves A and B). For trigger amplitudes below this level the device will go back to stable point 1 (curve C). The same is true for back-triggering from 2 to 1 (column 2 in Fig. 12). For the special load resistance and bias point considered here, the back-trigger pulse must be much larger than the forward-trigger pulse. This feature of the bistable circuit results from the fact that there exists a characteristic curve in the device current and device voltage plane (called separatrix) which separates all switching paths into two categories, one ending at stable point 1 [Fig. 11(b)] and the other at stable point 2. To trigger the circuit from one stable state to the other, it is necessary that the trigger pulse bring the device voltage and current beyond the separatrix. Otherwise, the circuit will return to the respective starting point. Column 3 in Fig. 12 gives the forward-triggering case for small inductances. It is interesting to note that after an initial drop in current the trace follows the load lines closely. Comparing columns 1 and 3, one also observes that the critical trigger amplitude depends on the external inductance.

Analysis

Some of the characteristic features of the bistable operation of the tunnel diode shall be explained by the following approximate calculations. We propose to show: 1) how the separatrix, which gives the minimum trigger amplitude for positive switching, can be calculated, when the device characteristic is approximated by straight lines; 2) how the device characteristic and the load line limit the switching speed of the tunnel diode in fast bistable operation.

1) When the device characteristic is approximated by a straight line through the unstable point 3 in Fig. 11(b) with a slope equal to that of the actual characteristic at this point, then the separatrix will also be a straight line through point 3. Its slope may be determined by the following argument.

Transforming (25a) and (26b) such that the unstable point is at the origin and replacing the device characteristic $i(v_J)$ by a straight line with slope (i/r_d), and then dividing (25a) by (26b) one gets

$$\frac{di_D}{dv_J} = \frac{di_d}{dv_j} = \frac{C_j}{L} \frac{[-v_j - i_d(r_s + r_L)]}{\left[i_d - \frac{1}{r_d} v_j\right]}. \tag{27}$$

Substituting in (27),

$$\frac{di_d}{dv_j} = \frac{i_d}{v_j} = m, \tag{28}$$

we find the slopes of the solution curves for this differential equation through the unstable point

$$m_{1,2} = \frac{1}{2}\left[\frac{1}{r_d} - \frac{r_s + r_L}{L} C_j \pm \sqrt{\left(-\frac{r_s + r_L}{L} C_j + \frac{1}{r_d}\right)^2 - \frac{4C_j}{L}}\right]. \tag{29}$$

For large values of L, m simplifies to

$$m_{1\infty} = \frac{1}{r_d} \tag{30}$$

$$m_{2\infty} = 0 \tag{31}$$

and for small L values one finds

$$m_{10} = -\frac{r_s + r_L}{L} \cdot C_j \tag{32}$$

$$m_{20} = -\frac{1}{r_s + r_L}. \tag{33}$$

These extreme cases are plotted in Fig. 13 (p. 1278).

The separatrices for all other values of L lie in the shaded area between m_{10} and $m_{1\infty}$. Comparing this result with the actual calculated trigger pulses in Fig. 12 one observes that for the forward-trigger pulse (columns 1 and 3) there is good agreement with the approximate calculations. The backward-trigger pulse, however, is not predicted well enough because in this case the straight line approximation for the separatrix is too inaccurate.

2) For small values of L the switching path and time can be predicted very well. When triggered beyond the separatrix the current will decrease very fast with the voltage constant until it hits the load line. Then it follows the load line until it settles at the stable point 2. Because this first drop in current at constant voltage is very fast, the switching time T is given by (25a) with $i_D = i_{DL}$ and $v_J \approx v_D$.

$$T = C_j \int_{v_{D0}}^{v_{D1}} \frac{dv_D}{i_{DL} - i(v_D)}. \tag{34}$$

Fig. 14 explains the symbols used in (34). From (34) the switching times for different trigger pulses have been determined by graphical integration using the device and load resistance employed in the computations (Fig. 12, Column 1). The upper limit in the integration has been chosen 10 mv below the stable point. Fig. 15 shows the results of these approximate calculations in comparison with the results obtained by the computer, solving the exact differential equations for different starting values. The agreement is reasonable.

From (34) and Fig. 14, one may conclude what tunnel-diode characteristics are desirable for very fast bistable operation:

1) C_j small,
2) peak current large,
3) peak current to valley current ratio high.

CONCLUSION

The preceding discussion tried to show how a computer can be used successfully to solve nonlinear circuit problems quantitatively. We only gave a very small selection of the problems which could be attacked in this way. This approach could be extended readily to such nonlinear problems as diode mixers, parametric amplifiers, distortion of low-frequency transistor oscillators and so on. All these problems have in common that the device and circuit can be described by nonlinear dc quantities and capacitances leading to a set of nonlinear but ordinary differential equations. A drastic extension of this approach must be made, when storage effects and time delays due to diffusion become important. A feasible approach to these more complicated problems would be to start with the nonlinear time-dependent transport equations in the different regions of the active semiconductor device and combine them into a set of nonlinear partial differential equations, in which arbitrary constants and functions are determined by measurements on the finished device.

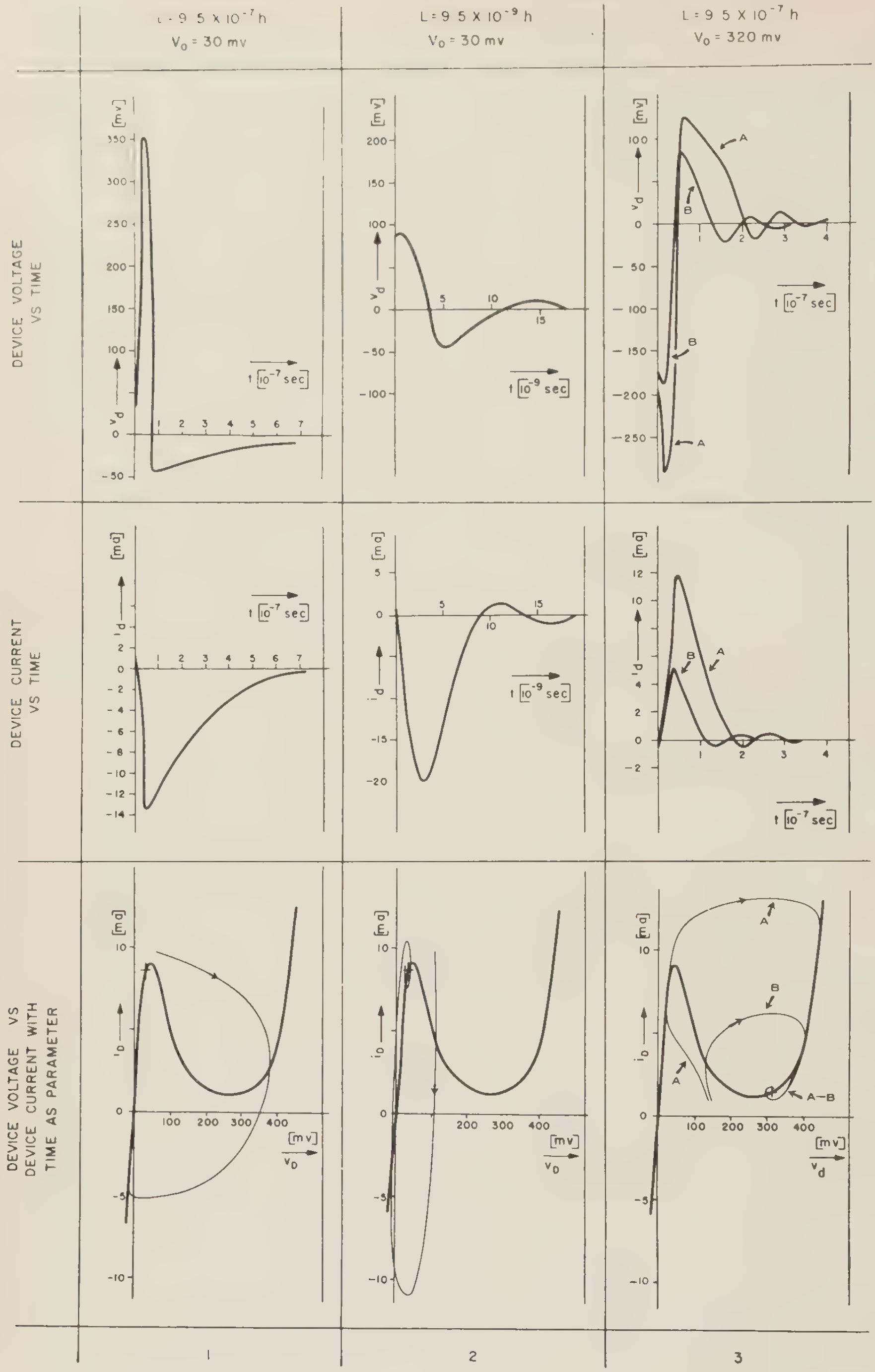
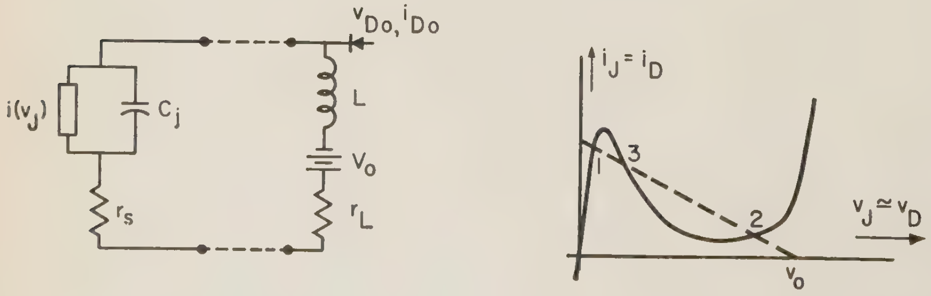


Fig. 10—Monostable switch.

Upper row: ac device voltage v_d as a function of time for three combinations of operating point and external inductance.

The third column shows the output patterns for two different trigger pulse amplitudes (*A*, *B*).


v_{Do}, i_{Do}
$i(v_J)$
C_j
L
V_0
r_s
r_L
$i_J = i_D$
1
2
3
$v_J \simeq v_D$
V_0

(a)

(b)

Fig. 11—(a) Circuit and (b) position of load line for operation of the tunnel diode as a bistable switch.

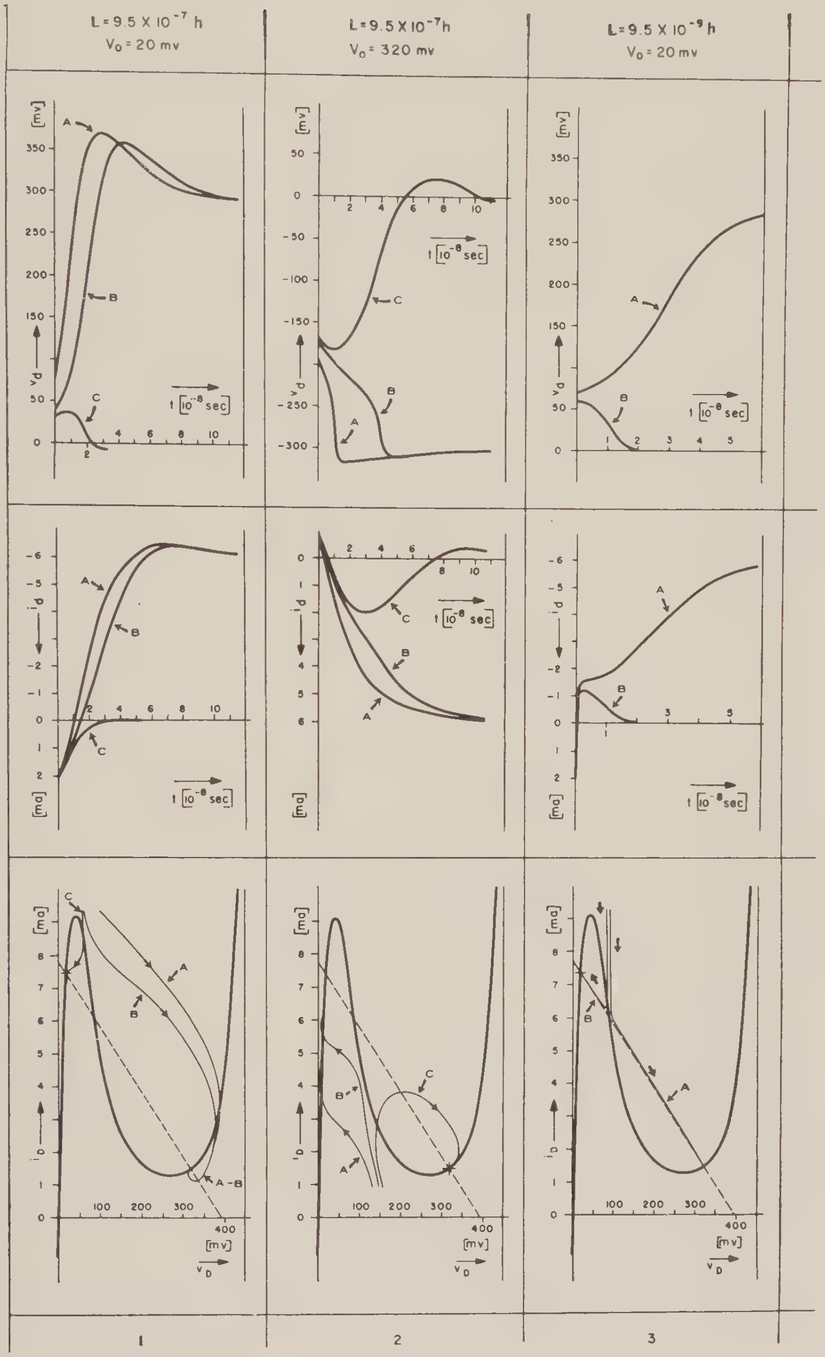


Fig. 12—Bistable switch

Upper row: ac device voltage v_d as a function of time for three combinations of operating point and external inductance under different trigger conditions.

Middle row: ac device current i_d as a function of time for different cases depicted in the upper row.

Lower row: dc device characteristic (heavy lines) and switching path, *i.e.*, instantaneous device current vs device voltage (light lines) for the cases depicted in the upper two rows.

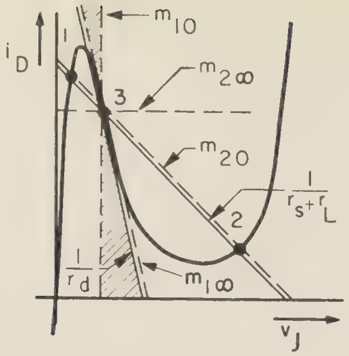


Fig. 13—Solutions of differential equations for bistable circuit in vicinity of the unstable point 3, when the nonlinear device characteristic in 3 is replaced by the tangent through this point. Cases shown are for large and small inductances.

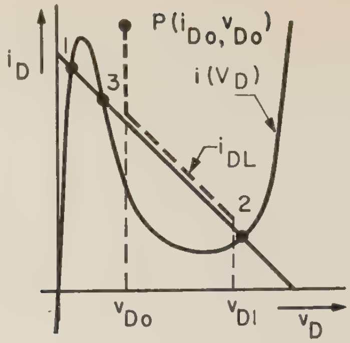


Fig. 14—Bistable swtiching path for small inductance (heavy dashed line), which can be used to calculate the switching time T for fast switching.

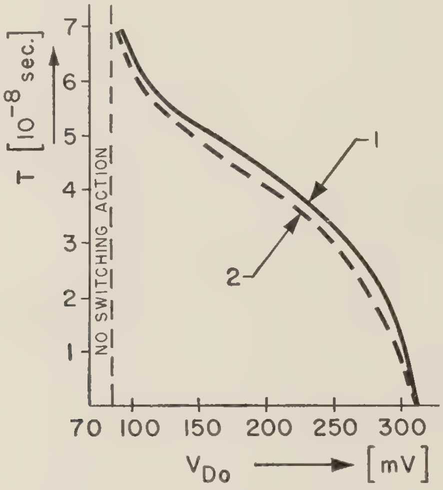


Fig. 15—Switching time of fast bistable switch vs trigger voltage. Curve no. 1 (solid) shows the results obtained by computer, solving the exact differential equations for different starting values, and curve no. 2 (dashed) the approximate results of graphically integrating (34). The bias point and the load line are the same as for Fig. 12, Column 1.

ACKNOWLEDGMENT

The authors would like to thank J. B. Herder from the U. S. Army Research and Development Laboratory of Fort Monmouth, N. J., for carrying out all the computer calculations.

IRE Standards on Solid-State Devices: Definitions of Terms for Nonlinear Capacitors, 1961*

61 IRE 28. S1

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Alternating Charge Characteristic. The function relating the instantaneous values of the alternating component of *transferred charge*, in a steady state, to the corresponding instantaneous values of a specified applied periodic *capacitor voltage*.

Note: The nature of this characteristic may depend upon the nature of the applied voltage.

Capacitance Ratio. The ratio of maximum to minimum capacitance over a specified voltage range, as determined from a capacitance characteristic, such as a *differential capacitance characteristic*, or a *reversible capacitance characteristic*.

Capacitor Voltage. The voltage across two terminals of a capacitor.

Differential Capacitance. The derivative with respect to voltage of a charge characteristic, such as an *alternating charge characteristic* or a *mean charge characteristic*, at a given point on the characteristic.

Differential Capacitance Characteristic. The function relating *differential capacitance* to voltage.

Ideal Capacitor. A capacitor whose *transferred charge characteristic* is single-valued.

Initial Differential Capacitance. *Differential capacitance* at zero *capacitor voltage*.

Initial Reversible Capacitance. *Reversible capacitance* at a constant bias voltage of zero.

Mean Charge. The arithmetic mean of the *transferred charges* corresponding to a particular *capacitor voltage*, as determined from a specified *alternating charge characteristic*.

Mean Charge Characteristic. The function relating *mean charge* to *capacitor voltage*.

Note: Mean charge characteristic is always single-valued.

Nonlinear Capacitor. A capacitor having a *mean charge characteristic* or a *peak charge characteristic* that is not linear, or a *reversible capacitance* that varies with bias voltage.

Nonlinear Ideal Capacitor. An *ideal capacitor* whose *transferred charge characteristic* is not linear.

Peak Charge Characteristic. The function relating one half the peak-to-peak value of *transferred charge* in the steady state, to one half the peak-to-peak value of a specified applied symmetrical alternating *capacitor voltage*.

Note: Peak charge characteristic is always single-valued.

Reversible Capacitance. The limit, as the amplitude of an applied sinusoidal *capacitor voltage* approaches zero, of the ratio of the amplitude of the resulting in-phase fundamental-frequency component of *transferred charge* to the amplitude of the applied voltage, for a given constant bias voltage superimposed on the sinusoidal voltage.

Reversible Capacitance Characteristic. The function relating the *reversible capacitance* to the bias voltage.

Transferred Charge (Capacitor). The net electric charge transferred from one terminal of a capacitor to another via an external circuit.

Transferred Charge Characteristic. The function relating *transferred charge* to *capacitor voltage*.

Voltage Coefficient of Capacitance. The derivative with respect to voltage of a capacitance characteristic, such as a *differential capacitance characteristic* or a *reversible capacitance characteristic*, at a point, divided by the capacitance at that point.

Voltage Sensitivity (Nonlinear Capacitor). See *Voltage Coefficient of Capacitance.*

Self-Oscillation in a Transmission Line with a Tunnel Diode*

J. NAGUMO†, MEMBER, IRE, AND M. SHIMURA†

Summary—Self-oscillation is observed in a transmission line with a tunnel diode on one end. The voltage waveform across and the current waveform through the tunnel diode are, in general, pulse form or stair-case form. This paper discusses the theoretical analysis of the circuit, and also presents the experimental results, which are in good agreement with the analysis.

This circuit can be used as a pulse or staircase wave generator, pulse-frequency modulator with discontinuous levels, analog-digital converter, etc. It is simple in construction, requires little source power, and has a wide frequency range (*e.g.*, μsec$\sim$mμsec).

I. INTRODUCTION

SELF-OSCILLATION is usually a problem associated with lumped constant systems. In this paper, self-oscillation in a distributed constant system is discussed.

In general, self-oscillation in a distributed constant system is described by a nonlinear partial differential equation, but it may also occur in a distributed constant system described by a linear partial differential equation (wave equation) and a nonlinear boundary condition.

Witt has considered the self-oscillation occurring in a string of a violin (the self-oscillation of the latter type), and has developed an elegant method of analysis.[1] Following this method, we have discussed the self-oscillation in a transmission line with a negative resistance element, *e.g.*, tunnel diode, *p-n-p-n* diode and others.

II. CIRCUIT AND FUNDAMENTAL EQUATION

A transmission line with the tunnel diode is shown in Fig. 1. In the following analysis, it is assumed that there are no losses in the line. The relation of the voltage v and the current i in the line becomes

$$\frac{\partial v}{\partial x} = -L\frac{\partial i}{\partial t}, \qquad \frac{\partial i}{\partial x} = -C\frac{\partial v}{\partial t}, \tag{1}$$

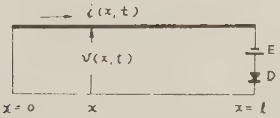

Fig. 1—Fundamental circuit of the tunnel diode connected to a transmission line.

where L is the series inductance, and C is the parallel capacitance per unit length of the line. Accordingly, eliminating i (or v),

$$\frac{\partial^2 v}{\partial x^2} = LC\frac{\partial^2 v}{\partial t^2} \qquad \left(\frac{\partial^2 i}{\partial x^2} = LC\frac{\partial^2 i}{\partial t^2}\right). \tag{2}$$

As the line is shorted at $x=0$ and connected with the tunnel diode at $x=l$, boundary conditions are

$$v(0, t) = 0 \tag{3}$$

$$i(l, t) = f(v(l, t) + E), \tag{4}$$

where E is the dc bias voltage, and $I=f(V)$ is the expression representing the characteristic curve of the tunnel diode.

It is assumed that the voltage along the line at $t=0$ is $\alpha(x)$ and the current is $\beta(x)$. Therefore, the initial conditions may be written as follows:

$$v(x, 0) = \alpha(x) \qquad (0 < x < l), \tag{5}$$

$$i(x, 0) = \beta(x) \qquad (0 < x < l), \tag{6}$$

where $\alpha(0)=0$.

The d'Alembert's solution of (2) is of the form

$$v(x, t) = \phi_1\left(t - \frac{x}{w}\right) + \phi_2\left(t + \frac{x}{w}\right), \tag{7}$$

where $w=(LC)^{-1/2}$ is the propagation velocity. From (1) and (7) it follows immediately that

$$i(x, t) = \frac{1}{Z}\left\{\phi_1\left(t - \frac{x}{w}\right) - \phi_2\left(t + \frac{x}{w}\right)\right\}, \tag{8}$$

where $Z=(L/C)^{1/2}$ is the characteristic impedance of the line.

The combination (3) and (7) gives

$$\phi_1(t) + \phi_2(t) = 0. \tag{9}$$

With the substitution of (9) into (7) and (8), the results are

$$v(x, t) = \phi_1\left(t - \frac{x}{w}\right) - \phi_1\left(t + \frac{x}{w}\right), \tag{10}$$

$$i(x, t) = \frac{1}{Z}\left\{\phi_1\left(t - \frac{x}{w}\right) + \phi_1\left(t + \frac{x}{w}\right)\right\}. \tag{11}$$

From (4), (10) and (11) we have

$$\begin{aligned}\phi_1\left(t - \frac{T}{2}\right) &+ \phi_1\left(t + \frac{T}{2}\right)\\ &= Zf\left(\phi_1\left(t - \frac{T}{2}\right) - \phi_1\left(t + \frac{T}{2}\right) + E\right),\end{aligned} \tag{12}$$

where $T/2=l/w$: the propagation time of waves in the line.

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[1] A. Witt, "Sur la théorie de la corde de violon," *Tech. Phys. USSR*, vol. 4, pp. 261–288; April, 1937.

Eq. (12) may be written as follows:

$$\phi_1\left(t+\frac{T}{2}\right)=g\left[\phi_1\left(t-\frac{T}{2}\right)\right]. \qquad (13)$$

This equation is a difference equation with the difference T. If $\phi_1(t)$ is given for $-T/2<t<T/2$, $\phi_1(t)$ may be successively determined for $T/2<t<3T/2$, $3T/2<t<5T/2, \cdots$.

As can be seen later, $g[\phi_1(t)]$ is a single-valued function or a triple-valued function. Especially when it is single valued, $\phi_1(t)$ is determined uniquely for $t>T/2$.

Now, from (5) and (10)

$$\phi_1\left(-\frac{x}{w}\right)-\phi_1\left(\frac{x}{w}\right)=\alpha(x) \qquad (0<x<l), \qquad (14)$$

and from (6) and (11)

$$\phi_1\left(-\frac{x}{w}\right)+\phi_1\left(\frac{x}{w}\right)=Z\beta(x) \qquad (0<x<l). \qquad (15)$$

Accordingly,

$$\phi_1\left(-\frac{x}{w}\right)=\frac{1}{2}\left\{\alpha(x)+Z\beta(x)\right\} \quad (0<x<l), \qquad (16)$$

$$\phi_1\left(\frac{x}{w}\right)=-\frac{1}{2}\left\{\alpha(x)-Z\beta(x)\right\} \quad (0<x<l). \qquad (17)$$

Eq. (16) gives $\phi_1(t)$ for $-T/2<t\leq 0$, and (17) for $0\leq t<T/2$. The value of $\phi_1(t)$ for $-T/2<t<T/2$, therefore, is determined by combining (16) with (17).

Thus, we intend to discuss the difference equation (12) or (13) in order to carry the analysis further.

III. ASYMPTOTIC BEHAVIOR

Introducing a new function $\varphi(t)$ by

$$\varphi(t)\equiv\phi_1\left(t-\frac{T}{2}\right),$$

(13) becomes as follows:

$$\varphi(t+T)=g[\varphi(t)]. \qquad (18)$$

It is assumed that the initial function is of the form

$$\varphi(t)=\varphi_0(t), \qquad (19)$$

where $\varphi_0(t)$ is a known function of t for $0<t<T$.

Let t_0 be a fixed time, and define a sequence $\{\varphi_n\}$ by

$$\begin{aligned}
\varphi_0 &= \varphi_0(t_0),\\
\varphi_1 &= \varphi_0(t_0+T)=g[\varphi_0(t_0)],\\
\varphi_2 &= \varphi_0(t_0+2T)=gg[\varphi_0(t_0)],\\
&\cdots\cdots\cdots\cdots\cdots\\
\varphi_n &= \varphi_0(t_0+nT)=gg\cdots(n)\cdots g[\varphi_0(t_0)].
\end{aligned}$$

Then the sequence $\{\varphi_n\}$ has two possible steady states as follows when $n\rightarrow\infty$.

1) There exists a certain value φ_∞ such that

$$\varphi_n=\varphi_\infty, \qquad \text{for } n=0,1,2,\cdots.$$

In this case, φ_∞ is given by

(Fig. 2).
$$\varphi_\infty=g[\varphi_\infty]. \qquad (20)$$

2) The steady state takes m alternative different values

$$\underbrace{\varphi_\infty^{(1)}\varphi_\infty^{(2)}\cdots\varphi_\infty^{(m)}}\;\underbrace{\varphi_\infty^{(1)}\varphi_\infty^{(2)}\cdots\varphi_\infty^{(m)}}\;\underbrace{\varphi_\infty^{(1)}\cdots}$$

cyclically (Fig. 3). In this case, $\varphi_\infty^{(s)}(1\leq s\leq m)$ satisfies the following relations:

a)
$$\varphi_\infty^{(s+1)}=g[\varphi_\infty^{(s)}] \qquad (1\leq s\leq m), \qquad (21)$$

where $\varphi_\infty^{(m+1)}\equiv\varphi_\infty^{(s)}$.

b)
$$\varphi_\infty^{(s)}=gg\cdots(m)\cdots g[\varphi_\infty^{(s)}]. \qquad (22)$$

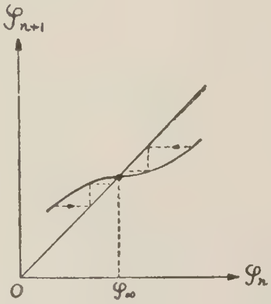

Fig. 2—When $|dg/d\varphi|<1$, the sequence $\{\varphi_n\}$ converges to φ_∞, and no oscillation can occur.

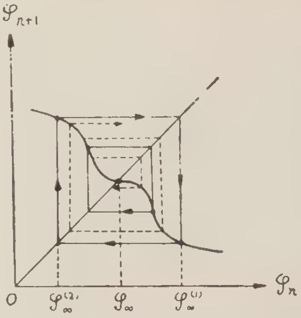

Fig. 3—The steady state takes two steady operating points ($\varphi_\infty^{(1)}$ and $\varphi_\infty^{(2)}$), alternatively.

Now let us consider the stability of these steady states. The steady state of case 1) is called stable when every sequence converges to φ_∞, of which sequence the initial value is in the ϵ neighborhood of φ_∞ at time $t=t_0$, where ϵ is some positive constant. The steady state which is not stable is called unstable. The stability of the periodic steady state [case 2)] may be defined as the same as case 1) for each $\varphi_\infty^{(s)}$ $(1\leq s\leq m)$.

For these definitions, the following stability criterion holds.

1) If

$$\left|\frac{dg[\varphi]}{d\varphi}\right|_{\varphi=\varphi_\infty} < 1, \tag{23}$$

then the steady state φ_∞ is stable (Fig. 2).

2) If

$$\left|\frac{dgg\cdots(m)\cdots g[\varphi]}{d\varphi}\right|_{\varphi=\varphi_\infty{}^{(m)}} < 1 \quad \text{for } 1 \le s \le m, \tag{24}$$

then the periodic steady state is stable (Fig. 3).

Eq. (24) can be rewritten as follows:

$$\left|\prod_{s=1}^{m}\left[\frac{dg[\varphi]}{d\varphi}\right]_{\varphi=\varphi_\infty{}^{(s)}}\right| < 1. \tag{25}$$

In general, $\{\varphi_n\}$ tends to a stable steady state as $n\to\infty$. It is worth mentioning that the above discussion does not give the complete explanation of the steady state, since the steady state discussed here depends upon the individual initial value $\varphi_0(t_0)$. (See Section V.)

IV. STEADY STATE

Eq. (12) may be written in the form

$$\varphi(t) + \varphi(t+T) = Zf(\varphi(t) - \varphi(t+T) + E), \tag{26}$$

where

$$\varphi(t) \equiv \phi_1(t - T/2).$$

With new variables ξ and η, (26) becomes

$$\eta = \frac{Z}{\sqrt{2}} f(\sqrt{2}\xi + E), \tag{27}$$

where

$$\xi = \frac{1}{\sqrt{2}}\{\varphi(t) - \varphi(t+T)\},$$

$$\eta = \frac{1}{\sqrt{2}}\{\varphi(t) + \varphi(t+T)\}. \tag{28}$$

Obviously, ξ and η are related with $v(l, t)$ and $i(l, t)$ by

$$\xi = \frac{1}{\sqrt{2}} v(l, t),$$

$$\eta = \frac{Z}{\sqrt{2}} i(l, t).$$

The voltage-current characteristic of the tunnel diode is illustrated in Fig. 4. The relation between ξ and η, therefore, becomes as shown in Fig. 5. Hence, the relation between $\varphi(t)$ and $\varphi(t+T)$ is obtained by rotating the curve of Fig. 5 45° to the right. This is shown in Fig. 6. In this relation, it is apparent that $|dg/d\varphi| < 1$ in the region where the resistance is positive $(f'(V) > 0)$, and $|dg/d\varphi| > 1$ where negative $(f'(V) < 0)$.

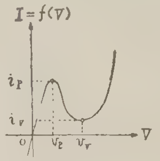

Fig. 4—The V-I characteristic of the tunnel diode.

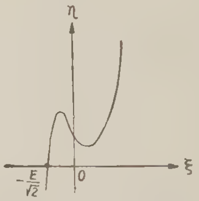

Fig. 5—The characteristic of the tunnel diode mapped on (ξ, η)-plane.

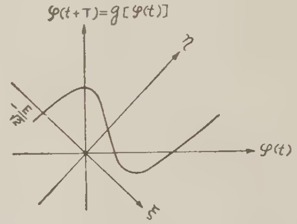

Fig. 6—The curve of the function g is obtained by rotating the ξ and η axes 45° to the right.

Let us write the negative resistance as

$$\rho(V) = -\left(\frac{dI}{dV}\right)^{-1} \qquad (\rho(V) > 0),$$

and define ρ_0 as

$$\rho_0 = \min_{\rho(V)\ge 0} \rho(V).$$

If

$$Z < \rho_0, \tag{29}$$

the function g of Fig. 6 is single valued, but if $Z > \rho_0$, it becomes triple valued in some region.

The steady state shows much difference owing to the dc bias voltage E and the characteristic impedance Z of the line. We must, therefore, discuss various cases.

A. $E < v_P$ or $E > v_V$

In this case, the curve g has a single intersection with η axis (45° line), and at the point, $|dg/d\varphi|$ is smaller than unity. Fig. 7 shows the case $E < v_P$, and Fig. 8 shows the case $E > v_V$.

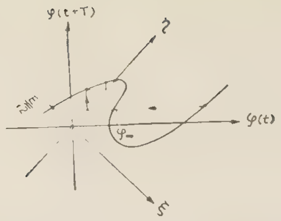

Fig. 7—The bias voltage E is smaller than v_P.

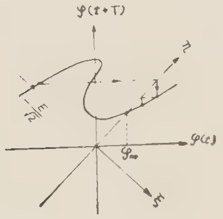

Fig. 8—The bias voltage E is larger than V_V.

Evidently, every sequence $\{\varphi_n\}$ with arbitrary initial value converges to φ_∞ as $n \to \infty$, where φ_∞ corresponds to this intersection. Therefore, $v(l, t)$ tends to zero as $t \to \infty$ for arbitrary initial condition. From this fact it is easily seen that no oscillation can occur in this case.

B. $v_P < E < v_V$

$|dg/d\varphi|$ is larger than unity at the intersection of the curve g with η axis (unstable). Thus, it is possible for various types of self-oscillations to occur. Some typical examples are discussed below.

1) Fig. 9 illustrates the case where the steady state takes two alternative values $\varphi_\infty{}^{(1)}$ and $\varphi_\infty{}^{(2)}$. In Fig. 10 let

$$\eta_P = \frac{Z}{\sqrt{2}}\, i_P,$$

$$\eta_V = \frac{Z}{\sqrt{2}}\, i_V,$$

and write three values of ξ corresponding to $\eta(\eta_V < \eta < \eta_P)$ as $\xi_1 > \xi_0 > \xi_2$, respectively (ξ_0 is not shown in the figure). Put

$$\xi_M = \tfrac{1}{2}\,(\xi_1 + \xi_2).$$

Then, the locus of the point (ξ_M, η) in the (ξ, η)-plane makes a curve by varying η in the interval $\eta_V \leq \eta \leq \eta_P$. The edge points of this curve are $(\xi_V{}^*, \eta_V)$ and $(\xi_P{}^*, \eta_P)$. Let η^* be the ordinate of the above mentioned curve corresponding to an arbitrary value of ξ^*, which lies in the intervals (ξ_P, ξ_V) and $(\xi_V{}^*, \xi_P{}^*)$ in common. Also, let $\xi_1{}^*$ and $\xi_2{}^*$ represent the values of ξ_1 and ξ_2 corresponding to $\eta = \eta^*$. Thus, it is evident that

$$\xi_1{}^* - \xi^* = \xi^* - \xi_2{}^*.$$

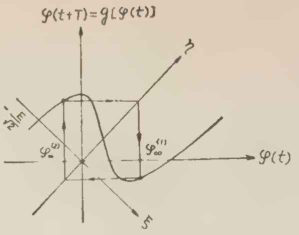

Fig. 9—When $v_P < E < V_V$, the steady state takes two steady operating points alternatively, and self-oscillation can occur.

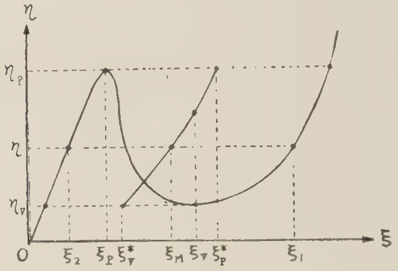

Fig. 10—The locus of the point (ξ_M, η).

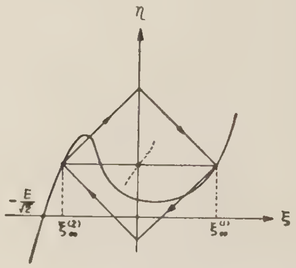

Fig. 11—One steady operating point is on the left positive resistance region, and one is also on the right. This is the case called $m = 1$, $n = 1$.

Fig. 11 shows the result in the case where the bias voltage is set at $E = \sqrt{2}\xi^*$, where $\xi_\infty{}^{(1)}$ and $\xi_\infty{}^{(2)}$ are given by

$$\xi_\infty{}^{(1)} = \xi_1{}^* - \xi^* = \frac{1}{\sqrt{2}}\left\{\zeta_\infty{}^{(1)} - \varphi_\infty{}^{(2)}\right\},$$

$$\xi_\infty{}^{(2)} = \xi_2{}^* - \xi^* = \frac{1}{\sqrt{2}}\left\{\varphi_\infty{}^{(2)} - \varphi_\infty{}^{(1)}\right\}.$$

Apparently, this steady state is stable.

If the characteristic impedance of the line is too high, it becomes not as in Fig. 11 but as in Fig. 15.

The voltage V across the tunnel diode, corresponding to $\xi_\infty{}^{(1)}$ and $\xi_\infty{}^{(2)}$, are

$$v_\infty{}^{(1)} = \sqrt{2}\xi_1{}^* = \sqrt{2}\left(\xi_\infty{}^{(1)} + \frac{E}{\sqrt{2}}\right),$$

$$v_\infty{}^{(2)} = \sqrt{2}\xi_2{}^* = \sqrt{2}\left(\xi_\infty{}^{(2)} + \frac{E}{\sqrt{2}}\right).$$

The voltage waveform is a square wave with period $2T$.

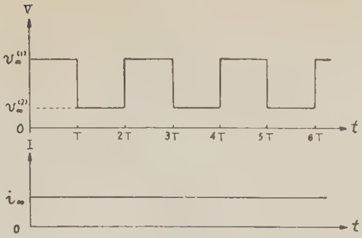

Fig. 12—The voltage and the current waveforms in the case $m=1$, $n=1$. The voltage waveform is a square one.

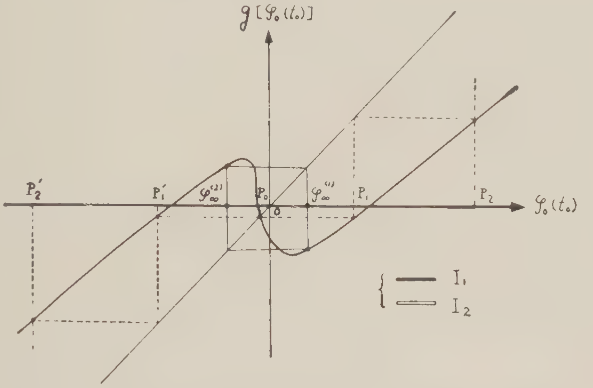

Fig. 13—An illustration of the effect of the initial condition.

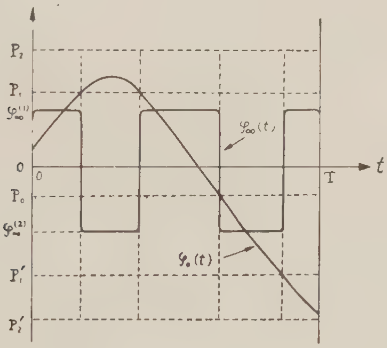

Fig. 14—The relation between the initial function $\varphi_0(t)$ and $\varphi(t)$ at the steady state. For the initial condition $\varphi_0(t_0) \in I_1$, the value of the steady operating point is $\varphi_\infty{}^{(1)}$, whereas for $\varphi_0(t_0) \in I_2$, the value is $\varphi_\infty{}^{(2)}$.

Let the current I through the tunnel diode be $i_\infty{}^{(1)}$ and $i_\infty{}^{(2)}$ corresponding to the voltage $v_\infty{}^{(1)}$ and $v_\infty{}^{(2)}$. Then the relation

$$i_\infty{}^{(1)} = i_\infty{}^{(2)} = i_\infty = \frac{\sqrt{2}}{Z}\eta^*$$

holds, showing that the current is constant (Fig. 12).

2) We will now discuss briefly the relation between the value of $\varphi(t)$ at the steady state ($\varphi_\infty{}^{(1)}$ or $\varphi_\infty{}^{(2)}$) and the initial value ($\varphi_0(t)$ at $t=t_0$). In Fig. 13 two kinds of intervals (I_1 and I_2) on the horizontal axis show the relation between the initial value $\varphi_0(t_0)$ and the value $\varphi(t)$ at the steady state ($\varphi_\infty{}^{(1)}$ or $\varphi_\infty{}^{(2)}$). If $\varphi_n \rightarrow \varphi_\infty{}^{(1)}$ for $\varphi_0(t_0) \in I_1$, then $\varphi_n \rightarrow \varphi_\infty{}^{(2)}$ for $\varphi_0(t_0) \in I_2$. Fig. 14 shows these circumstances situating for a half period T. The figure for the next half period is obtained by interchanging $\varphi_\infty{}^{(1)}$ and $\varphi_\infty{}^{(2)}$ in Fig. 14.

It is possible, therefore, to generate square waves with the period $2T/\nu$ (ν is an integer larger than 1) by choosing a suitable initial function $\varphi_0(t)$. When the initial voltage and the current distributions $\alpha(x)$ and $\beta(x)$ $(0<x<l)$ are nearly equal to zero, then

$$\zeta_0(t) = \phi_1\left(t - \frac{T}{2}\right) \doteqdot 0 \qquad (0 < t < T).$$

Hence, the voltage waveform becomes as in Fig. 12 but not as in Fig. 14.

3) It is seen from (27) that the curve is stretched along the η axis with increasing Z. Fig. 15 shows this case when the bias voltage is set on near v_P.[2] Fig. 16 shows the voltage and the current waveforms of this case with the period $3T$.

There are two steady operating points on the left side of the characteristic curve in Fig. 15, and one point on the right side. This follows from the fact that the bias voltage is nearer to v_P than v_V. If the bias voltage, therefore, is nearer to v_V than v_P, the number of the steady operating points is two on the right and one on the left. The case when Z is higher than that of Fig. 15 is shown in Fig. 17 and Fig. 18.

4) As the characteristic impedance Z becomes higher, the number of the steady operating points becomes greater. In Fig. 19 the bias voltage is set on near the middle point between v_P and v_V, and the number of the steady operating points are two on the left and three on the right. Fig. 20 shows the voltage and the current waveforms.

5) With a suitable bias voltage, the number of the steady operating points remain the same as in Fig. 19; however, the path from point to point is different, as shown in Fig. 21. The voltage and the current waveforms are illustrated in Fig. 22.

6) Let us consider the limit case as $Z \rightarrow \infty$. With very high Z, the figure compressed along the η axis becomes as in Fig. 23. Fig. 24 shows its voltage and current waveforms.

The self-oscillation in this case is quite near to the relaxation oscillation. In fact, it can be shown that the limit becomes the relaxation oscillation, as discussed below.

In Fig. 25 we have

$$\overline{DE} = \overline{BD} - \overline{BE} = \overline{BD} - \overline{EC} = \overline{BD} - \overline{DE}\tan\theta,$$

and hence

$$\overline{DE} = \frac{\overline{BD}}{1+\tan\theta} \doteqdot \frac{\overline{BD}}{\tan\theta}.$$

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[2] Refer to the Appendix for the method of construction.

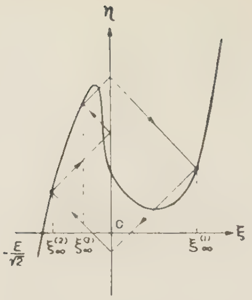

η
ξ
C
$-\frac{E}{\sqrt{2}}$
$\xi_\infty^{(2)}$
$\xi_\infty^{(3)}$
$\xi_\infty^{(1)}$

Fig. 15—The case $m=2$, $n=1$.

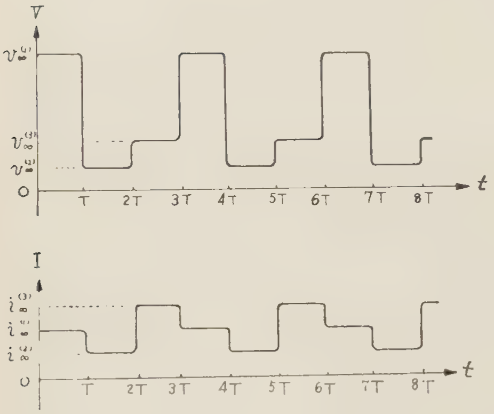


Fig. 16—The voltage and the current waveforms with period $3T$ in the case of Fig. 15.

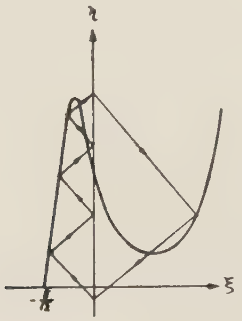

η
ξ
$-\frac{E}{\sqrt{2}}$

Fig. 17—The case $m=3$, $n=1$.

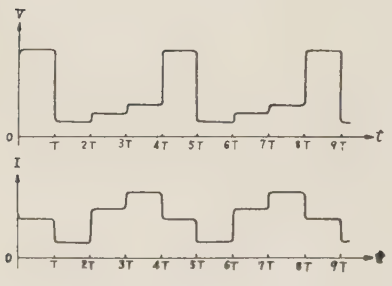


Fig. 18—The voltage and the current waveforms with period $4T$.

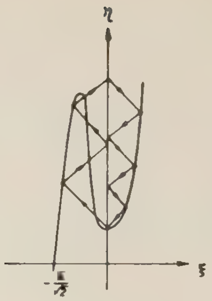

η
ξ
$-\frac{E}{\sqrt{2}}$

Fig. 19—The case $m=2$, $n=3$.

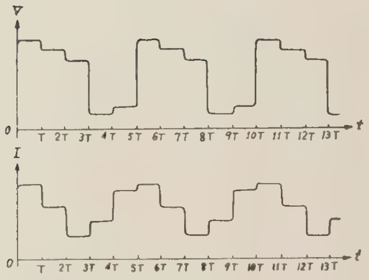


Fig. 20—The voltage and the current waveforms with period $5T$.

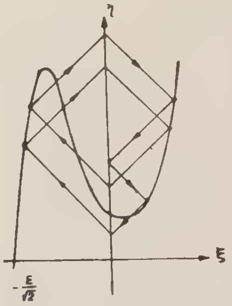

η
ξ
$-\frac{E}{\sqrt{2}}$

Fig. 21—The number of m and n is quite equivalent with that of Fig. 19. However, the path from point to point is different.

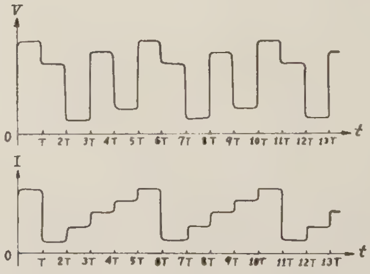


Fig. 22—The voltage and the current waveforms show many differences from those of Fig. 20.

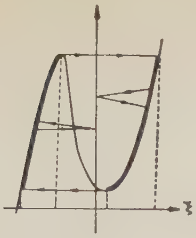


Fig. 23—The curve of the function g compressed along the η axis when Z is very large. In addition this figure shows the jump condition.

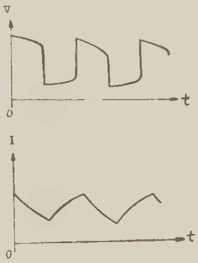


Fig. 24—The voltage and the current waveforms of Fig. 23 approach those of the relaxation oscillation as $Z \to \infty$.

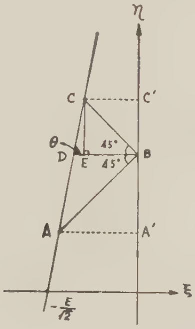


Fig. 25—A portion of the characteristic curve of the tunnel diode on (ξ, η)-plane.

As it is evident that

$$\tan \theta = \frac{d\eta}{d\xi} = Zf'(\sqrt{2}\xi + E) = Zf'(v + E),$$

the result is

$$\Delta\xi \doteqdot \frac{-2\xi}{Zf'(v+E)} = \frac{-2\xi}{\sqrt{L/C}\,f'(v+E)},$$

where

$$\overline{BD} = -\xi, \qquad \Delta\xi = \overline{AA'} - \overline{CC'} \doteqdot 2\overline{DE}.$$

If we write the time needed for the steady operating point running from A to C as

$$\Delta t = T = 1/2l\sqrt{L/C},$$

then

$$\frac{\Delta\xi}{\Delta t} \doteqdot \frac{-\xi}{lLf'(v+E)},$$

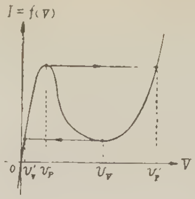


Fig. 26—Arrows show the jumping path of the relaxation oscillation.

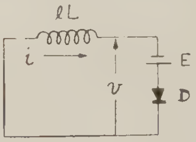


Fig. 27—The relaxation oscillation occurs in this circuit.

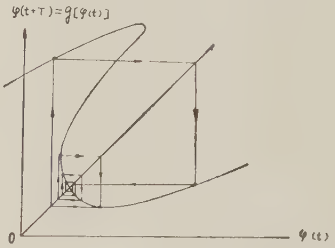


Fig. 28—When the bias voltage E is set on near the valley point of the tunnel diode characteristic, the steady operating points are observed on the negative-resistance region.

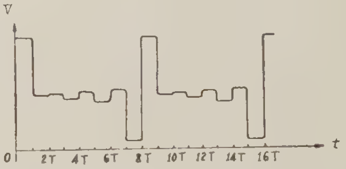


Fig. 29—The voltage waveform of Fig. 28.

or

$$\frac{\Delta v}{\Delta t} \doteqdot \frac{-v}{lLf'(v+E)}. \tag{30}$$

This difference equation may be approximated by the following differential equation:

$$\frac{dv}{dt} = \frac{-v}{lLf'(v+E)}. \tag{31}$$

In addition, from Fig. 26 the jump condition is obtained:

$$v_V \to V'_V, \qquad v_P \to V'_P \qquad (V = v + E). \tag{32}$$

On the other hand, if $C=0$, in Fig. 1, this circuit becomes that of Fig. 27. From Kirchhoff's law,

$$v = -lL\frac{di}{dt}, \qquad i = f(v+E). \tag{33}$$

Therefore, the differential equation of this circuit coincides with (31), and the jump condition with (32).

7) When the bias voltage E is set on near the valley point of the negative-resistance characteristic, the steady operating points are observed in the negative-resistance region. In this case, several rotations of the operating point are observed around the valley point, as shown in Fig. 28.

The number of rotations is restricted by the stability criterion:

$$\left|\prod_{s}\left[\frac{dg[\varphi]}{d\varphi}\right]_{\varphi=\varphi_\infty^{(s)}}\right| < 1.$$

If the number of rotations is too large, the left side of the above inequality becomes larger than unity, and the steady state will turn out unstable. Fig. 29 illustrates the voltage and the current waveforms. This case does not seem to be so stable.

V. General Conclusions

Summing up these results, we arrive at the following general conclusions. When the bias voltage E is set in the negative resistance region ($v_P < E < v_V$), self-oscillation is observed to occur in the transmission line. If this oscillation is observed by the voltage across the tunnel diode or the current through it, the oscillation generally has a staircase waveform. This waveform displays many differences, according to the characteristic impedance Z and the bias voltage E.

If the bias voltage E is set near the middle point between v_P and v_V, the number of the steady operating points on the left positive-resistance region (m) is nearly equal to that on the right (n). In the case where Z is low, $m=1$, $n=1$. The voltage waveform is a square one, and the current is constant. When Z increases, $m(\doteqdot n)$ becomes greater, and the oscillation approaches a relaxation oscillation.

In general, m is larger than n when E is near to v_P, and is smaller when E is near to v_V. There is more than one steady state which corresponds to the same m and n (except for the case $m=1$, $n=1$).

In any case, the period is $(m+n)T$. Thus, the period $2T$, corresponding to $m=1$, $n=1$, may be considered as the basic period, although it is not the shortest period as already seen in Section IV-B, 2).

VI. Effect of the Parallel Capacitance of the Tunnel Diode

In the previous sections we have neglected the parallel capacitance of the tunnel diode. If the parallel capacitance C_0 is considered in the circuit of Fig. 1, (4) becomes as follows:

$$i(l, t) = f(v(l, t) + E) + C_0\frac{\partial v(l, t)}{\partial t}\cdot \tag{34}$$

Therefore, (12) takes the form

$$\begin{aligned}\phi_1\left(t-\frac{T}{2}\right)+\phi_1\left(t+\frac{T}{2}\right) &= Zf\left(\phi_1\left(t-\frac{T}{2}\right)-\phi_1\left(t+\frac{T}{2}\right)+E\right)\\ &\quad + ZC_0\left\{\frac{d\phi_1\left(t-\frac{T}{2}\right)}{dt}-\frac{d\phi_1\left(t+\frac{T}{2}\right)}{dt}\right\}\cdot\end{aligned} \tag{35}$$

This is a differential-difference equation with the difference T.

By the initial conditions (5) and (6), the value of $\phi_1(t)$ for $-T/2<t<T/2$ is given as (16) and (17). Besides, the value of $d\phi_1(t)/dt$ can be determined for $-T/2<t<T/2$ by the equations

$$\frac{d\phi_1\left(-\frac{x}{w}\right)}{dx} = -\frac{w}{2}\left\{\frac{d\alpha(x)}{dx}+Z\frac{d\beta(x)}{dx}\right\} \qquad (0<x<l), \tag{36}$$

$$\frac{d\phi_1\left(\frac{x}{w}\right)}{dx} = -\frac{w}{2}\left\{\frac{d\alpha(x)}{dx}-Z\frac{d\beta(x)}{dx}\right\} \qquad (0<x<l). \tag{37}$$

If the values of $\phi_1(t)$ and $d\phi_1(t)/dt$ are given for $-T/2<t<T/2$, (35) becomes a first-order differential equation of $\phi_1(t)$ for $T/2<t<3T/2$. Therefore, assuming that $\phi_1(t)$ is continuous at $t=T/2$, $\phi_1(t)$ may be determined for $T/2<t<3T/2$. In a like manner, $\phi_1(t)$ may be successively determined for $3T/2<t<5T/2$, $5T/2<t<7T/2$, $\cdots$.

Now, setting $\varphi(t)\equiv\phi_1(t-T/2)$, (35) may be written

$$C_0\frac{d\varphi(t+T)}{dt} = G\left(\varphi(t+T), \varphi(t), C_0\frac{d\varphi(t)}{dt}\right), \tag{38}$$

where

$$\begin{aligned}G\left(\varphi(t+T), \varphi(t), C_0\frac{d\varphi(t)}{dt}\right) &= f(\varphi(t)-\varphi(t+T)+E)\\ &\quad -\frac{1}{Z}\{\varphi(t+T)+\varphi(t)\}+C_0\frac{d\varphi(t)}{dt}\cdot\end{aligned}$$

Let us consider this differential-difference equation under the initial function:

$$\varphi(t) = \varphi_0(t) \qquad (0 \leq t \leq T), \tag{39}$$

where $\varphi_0(t)$ is a given function of t for $0\leq t\leq T$. Henceforth, we assume that the initial function and its first derivative are continuous for $0\leq t\leq T$. Clearly, this assumption is satisfied if $d\alpha(x)/dx$ and $d\beta(x)/dx$ are continuous for $0\leq x\leq l$, and $d\beta(x)/dx=0$ at $x=0$.

In order that the solution of this equation has physical significance, it must be "stable" in some sense. It seems reasonable for us to define the stability of the solution of (38) as follows. Let $\varphi(t|\varphi_0(t))$ be the solution of (38) corresponding to the initial function $\varphi_0(t)(0\leq t\leq T)$. The solution $\varphi(t|\varphi_0(t))$ is said to be stable if we can find a $\delta=\delta(\epsilon)>0$ for every $\epsilon>0$, such that, for any initial function $\varphi_0^*(t)(0\leq t\leq T)$ which satisfies

$$\text{Max} \left| \varphi_0(t) - \varphi_0^*(t) \right| < \delta,$$

$$\text{Max} \left| d\varphi_0(t)/dt - d\varphi_0^*(t)/dt \right| < \delta \qquad \text{for } 0 \leq t \leq T,$$

we have

$$\left| \varphi(t \mid \varphi_0(t)) - \varphi(t \mid \varphi_0^*(t)) \right| < \epsilon \qquad \text{for } t \geq T.$$

If $C_0=0$, (38) takes the form

$$G(\varphi(t + T), \varphi(t), 0) = 0. \tag{40}$$

This equation is called a "degenerate equation," corresponding to (38), and is nothing but the difference equation (18). It is already known that (40) has the discontinuous periodic solution (staircase waveform) under suitable conditions.

We are now in a position to investigate the following problems.

1) Does the differential-difference equation (38) have a periodic solution, and especially, a stable one? If it does, how do its waveform and period depend upon the value of C_0? This problem has practical importance in relation to the rise time of pulses when this circuit is used as a pulse generator.

2) In the case where (38) has a stable periodic solution, which one of the discontinuous periodic solutions of the degenerate equation (40) does the stable periodic solution of (38) approach as $C_0 \to 0$?

As discussed, three $\varphi(t+T)$ correspond to one $\varphi(t)$, when the function g is triple-values. Which one of these three is actually selected is a problem which is closely connected with the latter problem mentioned above. To establish a complete explanation of all the circuit behaviors, it is necessary to investigate these problems fully. We shall refrain from doing so, however, but we shall indicate the direction of the further approach.

VII. SYNCHRONIZATION OF THE SELF-OSCILLATION

It is well known that self-oscillation may be generally synchronized by the external periodic oscillation. The same phenomenon was seen concerning the self-oscillation discussed in this paper. The fractional synchronization was also observed, but the basic synchronization had wider synchronous region. This problem can be analyzed by treating the periodic solution of the period $2\pi/\omega$ of the nonautonomous differential-difference equation which is obtained by replacing $E+e \sin \omega t$ for E in (38).

VIII. USE OF THE CURRENT-CONTROLLED NEGATIVE-RESISTANCE ELEMENT

When the current-controlled negative-resistance element (*e.g.*, *p-n-p-n* diode, double-base diode, electric discharge tube and arc, etc.) is used instead of the tunnel diode (voltage-controlled element), the transmission line must be open at the end $x=0$ (Fig. 30). In this case, the analysis can be made in the same manner as above by interchanging voltage and current, impedance and admittance.

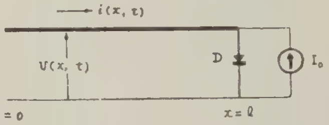


Fig. 30—A circuit using a current-controlled negative-resistance element.

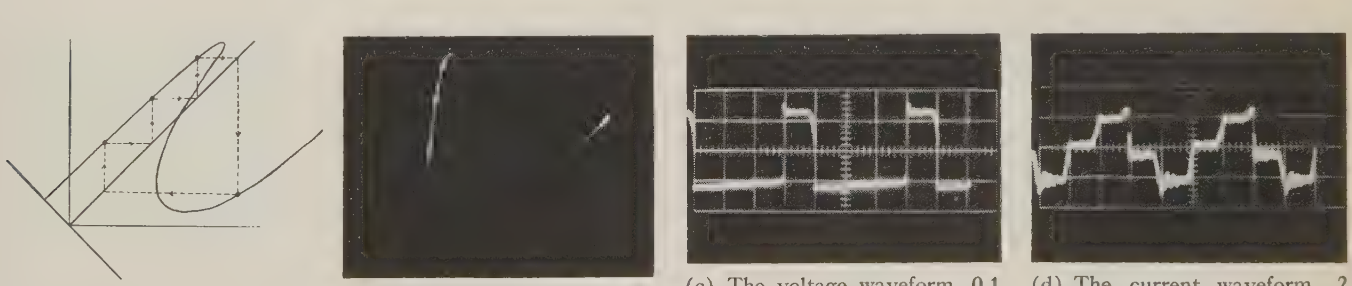
IX. EXPERIMENTAL RESULTS

As a transmission line, we used an LC lumped-constant delay line, conventional delay line, coaxial line, parallel wires (feeder line for television) and Lecher wires.

Using the LC lumped-constant delay line with $Z=220$ Ω, we observed various types of self-oscillations, $m=1$, 2, 3, 4, $n=1$, 2, 3. Some of these waveforms are shown in Figs. 31–36. We could also observe three modes for the case $m=1$, $n=1$, corresponding to different initial conditions.

The effect of the parallel capacitance of the tunnel diode increases the rise and fall times of a pulse.

Figs. 31(a) and 32(a) show steady operating points as determined graphically. Bright spots on the V-I characteristic curve of Figs. 31(b), 32(b) and 33(a) indicate those points as they appeared on a cathode-ray tube. These waveforms were observed by a 30-Mc synchroscope.



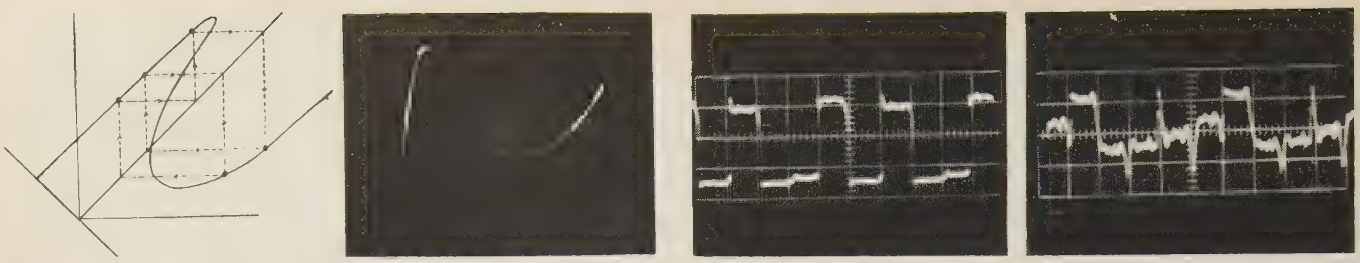
(a)

(b) The V-I characteristic.

(c) The voltage waveform. 0.1 volt/division (vertical). 900 μsec/division (horizontal).

(d) The current waveform. 2 ma/division (vertical). 900 μsec/division (horizontal).

Fig. 31—The case $m=3$, $n=1$. (3:1) $Z=220$ Ω. $T/2=450$ μsec. $E=0.140$ volt.



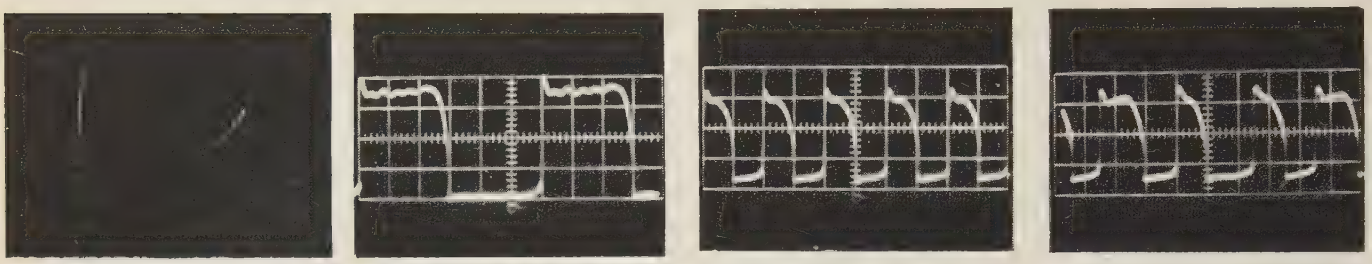
(a)

(b) The V-I characteristic.

(c) The voltage waveform. 0.1 volt/division (vertical). 900 μsec/division (horizontal).

(d) The current waveform. 2 ma /division (vertical). 900 μsec /division (horizontal).

Fig. 32—The case $m=3$, $n=2$. [(2:1)$\rightleftarrows$(1:1)] $Z=220\ \Omega$. $T/2=450\ \mu$sec. $E=0.223$ volt.



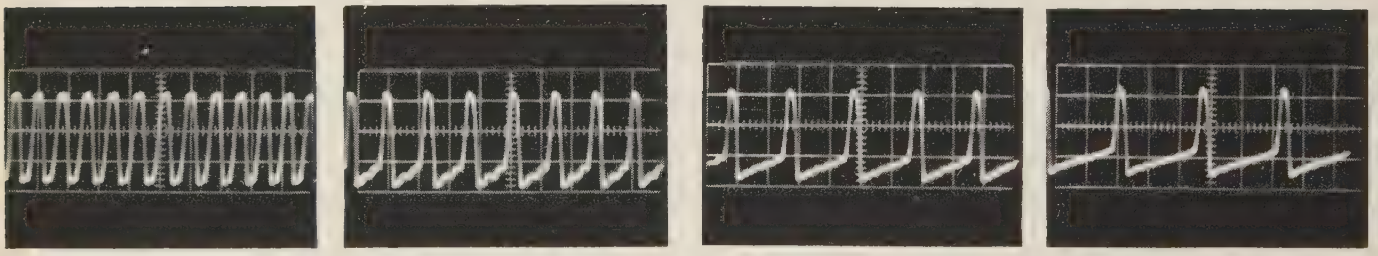
(a) The V-I characteristic.

(b) The voltage waveform of the fundamental mode (Mode 1).

(c) Mode 2.

(d) Mode 3.

Fig. 33—The three modes of the case $m=1$, $n=1$, corresponding to the different conditions. $Z=220\ \Omega$. $T/2=450\ \mu$sec. $E=0.240$ volt. Each division indicates 0.1 volt (vertical) and 300 μsec (horizontal).



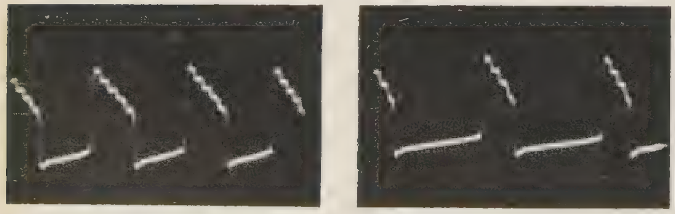
(a) The case $m=1$, $n=1$. $E=0.120$ volt.

(b) The case $m=3$, $n=1$. $E=0.082$ volt.

(c) The case $m=5$, $n=1$. $E=0.067$ volt.

(d) The case $m=7$, $n=1$. $E=0.060$ volt.

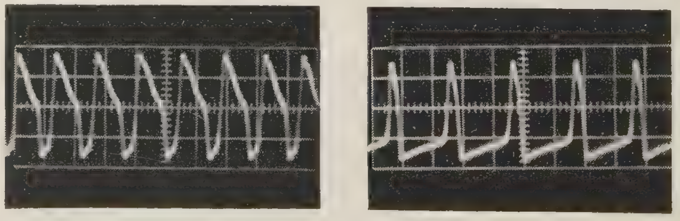
Fig. 34—The voltage waveforms when the coaxial lines with $Z=75\ \Omega$ and $T/2=13$ mμsec is used. Each division indicates 0.1 volt (vertical) and 100 mμsec (horizontal).



(a) $E=0.133$ volt.

(b) $E=0.093$ volt.

Fig. 35—The voltage waveforms with use of the parallel line (feeder line for television) with $Z=300\ \Omega$ and $T/2=20$ mμsec. 0.1 volt /division (vertical) and 150 mμsec/division (horizontal).



(a) $E=0.068$ volt.

(b) $E=0.172$ volt.

Fig. 36—The voltage waveforms with use of the Lecher wires with $Z=260\ \Omega$ and $T/2=8.5$ mμsec. 0.1 volt/division (vertical) and 100 mμsec/division (horizontal).

X. REMARKS

The self-oscillation discussed in this paper can be explained as the periodic solution of the linear wave equation with a nonlinear (negative-slope) boundary condition. If the nonlinear boundary condition is resistive, the problem reduces to a nonlinear difference equation, while, if reactive, it becomes a nonlinear differential-difference equation.

Many examples represented by this scheme are seen in mechanical systems. Table I shows the correspondence between such examples and the circuit considered in this paper. From this table, we conclude that this circuit is a simulator of almost all stringed and wind instruments.

APPENDIX

METHOD OF CONSTRUCTION

In Fig. 37 the curve $A'B'$ is the mapping of the right portion AB of the characteristic curve. If we write the coordinate of the point A as $(\varphi(t),\ g[\varphi(t)])$, that of the point A' is $(g^{-1}[\varphi(t)]\ g[\varphi(t)])$. The mirror image of the curve CD is drawn for the 45° line, and its intersection with the curve $A'B'$ is obtained. When this point is shifted horizontally into the right portion of the characteristic, the new point gives one of the steady operating points of the case $m=1$, $n=2$, provided that the shifted point falls in the interval $(p,\ q)$. If the curve $A''B''$, mapped once again, is used instead of $A'B'$, one of the steady operating points of the case $m=1$, $n=3$ is obtained. In the same way, the intersection of the curve $A''B''$ with the mirror image of the curve $C'D'$, the mapping of the left portion CD, gives one of the steady operating points of the case $m=2$, $n=3$.

TABLE I

Mathematical Expression		Linear Wave Equation	Nonlinear (Negative-Slope) Boundary Condition		
System	Example	Distributed Constant System	Element	Position	Characteristic
Electric system	Our circuit	Transmission line	Tunnel diode	One edge of the line	Voltage-current
Mechanical system	Violin	String	Coulomb friction	Contact point of string with bow	Frictional force-relative velocity
Fluid system	Water hummer	Water duct	Valve	One edge of the duct	Pressure-flow
Sound system	Wind instruments	Air duct	Lips	One edge of the duct	Pressure-flow

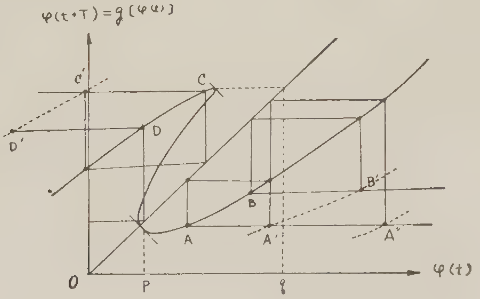


Fig. 37—Steady operating points can be obtained graphically. The curve $A'B'$ is obtained by mapping the curve AB as shown in the figure.

IRE Standards on Solid-State Devices: Measurement of Minority-Carrier Lifetime in Germanium and Silicon by the Method of Photoconductive Decay*

61 IRE 28. S2

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1. GENERAL

1.1 Scope

This standard describes a particular method for measuring carrier lifetime, namely, that of photoconductive decay. Lifetime (volume) is defined[1] as: "the average time interval between the generation and recombination of minority carriers in a homogeneous semiconductor." Numerous methods for measuring carrier lifetime have been described, but this present standard concerns itself with the technique which has gained most widespread use. Discussion of basic theory and reference to other techniques will be found in the review paper by Bemski.[2]

This standard concerns measurements on both germanium and silicon, and in particular, describes the analysis of nonexponential decays often found in the case of silicon measurements.

The smallest lifetime measurable by this method is determined by the turnoff time of the light sources as described in Section 2.2.1. The maximum measurable lifetime is determined by the diffusion constant D and the sample dimensions. Detailed limits for both n- and p-type germanium and silicon are presented in Table I (see Appendix).

1.2 General Procedure

In the photoconductive-decay method, a constant current is passed through a semiconducting filament equipped with ohmic contacts, and the voltage drop down the filament is monitored continuously. For a short period, excess carriers are deliberately created in the body of the filament—usually by exposure to visible or near infrared illumination, though high-energy electromagnetic rays or beams of high-energy particles may be used.

It is not usually desirable to employ exciting rays which are too strongly absorbed by the semiconductor, for then most of the excess carriers are created near the front surface of the specimen and tend to recombine on this surface. A filter made of the same semiconductor as the specimen itself is often interposed between the light source and the specimen. This eliminates the short-wavelength nonpenetrating photons, but passes a fair proportion of those wavelengths near the absorption edge which can be absorbed reasonably uniformly throughout the thickness of the specimen.

In thermal equilibrium, the voltage drop along the section of the specimen to be illuminated is V_0 for a given constant current. When illumination starts, the voltage decreases, since additional carriers are being provided to support the current. The excess-carrier lifetime can be determined from observations of the change in voltage, $\Delta V = (V_0 - V)$ during the period of conductance buildup; however, it is more useful to study the decay of ΔV when the light is suddenly turned off. During the latter period excess holes and electrons are progressively made unavailable for conduction through recombining and trapping processes.

---

[1] "IRE Standard on Solid-State Devices, Definitions of Semiconductor Terms, 1960: 60 IRE 28. S1," Proc. IRE, vol. 48, pp. 1772–1775; October, 1960.

[2] G. Bemski, "Recombination in semiconductors," Proc. IRE, vol. 46, pp. 990–1004; June, 1958.

The two excess populations are equal in density only when recombination is the dominant factor. During the decay the excess conductivity $\Delta\sigma$ varies as

$$\begin{aligned}\Delta\sigma &\propto \Delta p = \Delta n\\ &\propto \exp\left[-t/\tau\right],\end{aligned} \tag{1}$$

where Δp and Δn are, respectively, the concentrations of excess holes and excess electrons, and τ is a characteristic time constant.

For a specimen operated under constant-current conditions, voltage is inversely proportional to conductance. Hence, for small deviations from thermal-equilibrium conditions, ΔV is directly proportional to excess conductance but is of the opposite sign. (Corrections for large modulation appear in Section 2.4.2.) Accordingly, the effective measured lifetime, ordinarily called the filament lifetime, τf at any instant is given by

$$\tau f = -\Delta V\left[d(\Delta V)/dt\right]^{-1} \quad \text{when} \quad \Delta V \ll V_0 \tag{2}$$

and by an appropriately modified form for strongly modulated conditions. The recombination mechanisms which jointly determine τf will include both volume and surface effects. It is necessary to take precautions to calculate the surface contribution if volume lifetime is to be measured adequately.

The time scale of decay does not correctly portray the lifetime behavior if trapping is serious, either in the recombination levels or in separate traps of poor recombinative efficiency. Excess holes and electrons then will contribute to the photoconductance in a manner which changes as the trapping proceeds. While excess carriers of one type are trapped, a corresponding concentration of the opposite type is forced to remain in circulation; these contribute a long-period tail to the photoconductance, which declines slowly as the traps finally empty.

Trapping is most serious at low temperatures, but in silicon it can be significant at room temperature for small light intensities. In these cases it is still often possible to measure the lifetime corresponding to large excess concentrations, since traps may tend to become saturated. The necessary conditions can be arranged either by observing the early stages of decay following an intense flash of light or by using a weaker light flash in conjunction with strong continuous illumination.

2. DETAILED PROCEDURE

2.1 Preparation of Samples

2.1.1 Surface Preparation: The surface should be sandblasted or ground. This provides a reference surface for which the surface recombination rate of the fundamental mode is

$$\nu_s = \pi^2 D\left[\frac{1}{a^2} + \frac{1}{b^2} + \frac{1}{c^2}\right], \tag{3}$$

where a, b and c are the dimensions of the sample, and should be expressed in centimeters if the diffusion constant D is given in cm^2/sec. In general, the ambipolar diffusion constant, defined by (4),

$$D = \left[\frac{n+p}{\left(\frac{n}{D_p}\right) + \left(\frac{p}{D_n}\right)}\right] \tag{4}$$

should be used in the calculation of the surface-recombination rate; however, this reduces to D_p for strongly n-type material and to D_n for strongly p-type material. Only with germanium of higher resistivity than 20 ohm-cm is it imperative to use D in the form of (4).

Once the surface-recombination rate ν_s has been calculated, it is possible to compute the volume lifetime τB from the filament lifetime τf, using

$$\tau B = \left[\frac{1}{\tau f} - \nu_s\right]^{-1} \tag{5}$$

and subject to the restriction that penetrating light is employed (see Section 2.2 below).

2.1.2 Sample Shape and Size: Three standard sizes of samples are given in the Appendix. Table I of the Appendix gives the maximum values of volume lifetime measurable with the different sizes; Table II of the Appendix gives the surface-recombination rate ν_s calculated from (3) and used in (5). If no knowledge of lifetime range is available before the measurement, the largest size sample possible should be used. In addition to providing a calculable surface effect, sandblasting or grinding of the surfaces greatly reduces the importance of surface cleanliness and ambient gas.

2.1.3 Contact Preparation: End contacts should cover the entire ends and should not make contact with the sides of the sample. The contacts should be nonrectifying. This condition should be tested by observing the voltage across the sample corresponding to each polarity of the constant-current source. If these two voltages are within 2 per cent of each other, the contacts can be regarded as satisfactory for a lifetime measurement. It is recommended that the necessary ohmic contacts on germanium be applied by soldering or by plating. In the case of silicon it is recommended that the necessary ohmic contacts be applied by an ultrasonic soldering method. For p-type silicon pure indium, and for n-type silicon, an alloy of 95 per cent tin, 5 per cent antimony, gives satisfactory behavior.

2.1.4 Resistivity Uniformity: The resistivity profile of the sample is measured according to presently accepted techniques.[3] The lowest resistivity should not differ from the highest resistivity by more than 10 per cent.

2.1.5 Photo Voltage: With the sample current set at zero any photovoltaic signal should have a peak amplitude less than 1 per cent of the desired photoconductive signal.

2.2 Optical Requirements

The illuminating system is required to deliver a pulse of light with a very short turn-off time. An arrangement of mirrors and/or lenses is usually included to collect as much of the available light as possible and direct this to the front face of the specimen. The inclusion of a filter (made from the same semiconductor as the specimen) in the optical path insures that nonpenetrating light does not reach the specimen. Since radiation of wavelengths longer than the absorption edge does not produce free hole-electron pairs, it is only the intensity in a wavelength interval immediately around 1.1 μ (for silicon) or 1.7 μ (for germanium) which determines the carrier generation rate in the specimen. The amount of this light depends on the type of light source as discussed below.

2.2.1 Desired Behavior of Light Source: Several types of pulsed light sources have been used successfully. These included mechanical choppers, rotating mirror systems, short-duration arc sources and electro-optical shutters. The light intensity normally should be maintained at a level such that the filament conductance changes by less than 5 per cent. When measurements are made with larger modulation, it is necessary to follow the procedure of Section 2.4.2 for correcting Δn and τ. The turn-off time of the light sources must be short compared with the filament lifetime (light intensity down to 10 per cent in 0.2 τf or less). An n-type germanium sample with $a=1.0$ cm, $b=0.4$ cm, $c=0.025$ cm, with all surfaces ground or sandblasted may be used to test the turn-off time of the pulsed light source. This sample will have a filament lifetime of less than about 1 μsec regardless of the bulk lifetime of the germanium used. In the case of silicon, a sample 0.010 cm thick would be required to insure a filament lifetime less than 1 μsec.

In one preferred type of source a capacitor is charged to several thousand volts and discharged through a spark gap or Xenon flash tube. With a capacitor of some 0.01 μf a bright discharge can be obtained which reaches maximum intensity within 0.3 μsec and is down to less than 5 per cent of this intensity in an additional 0.5 μsec. The fast decay of light intensity is necessary, for otherwise falsely long lifetimes will be ascribed to material in which the rate of carrier recombination is comparable with the rate of light decay. When measuring a sample with a lifetime of less than 5 μsec, it is preferable to use a smaller capacitor for a shorter pulse duration, even though the total available light flux is then smaller. A triggered repetition rate of the order of 20 to 60 cps for the light source will result in a steady oscillographic display which is convenient to adjust and not fatiguing to the eyes.

In a different kind of light source, the output of a continuously operated lamp (usually a tungsten ribbon at 3000°K) is modulated by a rotating mirror or Kerr cell. This form of source is less efficient than a spark gap or flash tube in that the heated ribbon is capable of providing only 10 per cent as many photons per square centimeter of source per second at 1.1 μ. When a mirror is rotated fast enough to produce a pulse which decays in less than 1 μsec, the light intensity at the sample may be small. The Kerr cell has the advantage that the length and shape of the light pulse can very easily be made variable.

2.2.2 Optical Filtering: The light is passed through a polished filter of the same semiconductor as the lifetime sample with thickness and temperature comparable with that of the sample. The filter is perpendicular to the beam and parallel to the sample. Considerable displacement of the light occurs if the two are misoriented because of the high refractive indices of silicon and germanium. A good position for the filter is immediately in front of the specimen.

2.2.3 Sample Area to be Illuminated: The region surrounding the end contacts is shielded from light. It is further recommended that masking strips should be placed along the specimen so that only approximately the center half of the total width is exposed to light. When measurements are made under these conditions, the electric field within the sample should satisfy the inequality

$$E \leq \frac{300}{\sqrt{\tau\mu}} \frac{\text{volt}}{\text{cm}}, \tag{6}$$

where τ is here expressed in microseconds and

$$\mu = \frac{\mu_n\mu_p \left| n_0 - p_0 \right|}{n_0\mu_n + p_0\mu_p} \frac{\text{cm}^2}{\text{volt} - \text{sec}}. \tag{7}$$

For material which is strongly n-type or p-type the latter expression becomes μ_p or μ_n, respectively.

With the specimen masked as described, the exposed area should be illuminated as uniformly as possible.

2.2.4 Background Illumination: Occasionally background light has been used to saturate traps in silicon. However, in the general case it is recommended that a background light should not be used. The presence of traps in a particular sample should be noted and the lifetime qualified. (See Section 2.4.1.)

---

[3] See for example, L. B. Valdes, "Resistivity measurement on germanium for transistors," Proc. IRE, vol. 42, pp. 420–427; February, 1954.

2.3 *Electric Circuit and Operating Procedure*

The components of the measuring system to be used are shown in Fig. 1. The current source may either be a battery or a hum-free power supply. In series with this is a nonreactive low-noise resistor R_L, whose resistance must be at least 20 times greater than the sample resistance (so that a constant current is preserved during illumination). A multirange micro- and milliammeter is desirable for observing the actual current I. V_B and R_L will normally be adjustable either continuously or in steps. The photoconductive-decay pattern should be observed for both polarities of the constant-current source. It is convenient to take the output signal to the preamplifier and oscilloscope from the side of the reversing switch remote from the specimen, so that the oscilloscope display is not inverted when the specimen current is reversed. When a flash of light occurs, the oscilloscope may be triggered either directly from the light source or from the rise of the photoconductive signal ΔV. It is preferable to trigger the scope by the light source, since this guarantees that the entire decay can be viewed.

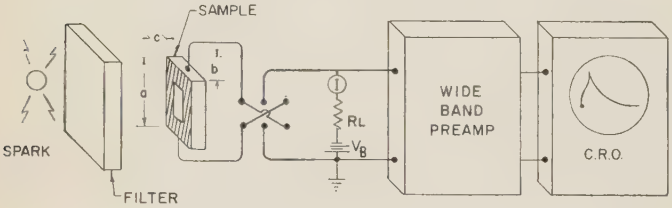

Fig. 1—Schematic circuit arrangement.

2.3.1 Precaution: The specimen is to be mounted in a metal box which provides adequate electrical shielding. All connections between parts of the system are to be made with shielded cables which must be kept as short as possible. "Sweep-out" of charge carriers must be obviated by use of a sufficiently small electric field in the sample. For specimens of $\tau<100$ μsec, a field of up to 0.5 v/cm may be permissible, but a smaller field must be used for material of longer lifetime in accordance with (6). The criterion of satisfactory field for any specimen must finally rest on the observation that the lifetime does not depend on the magnitude or polarity of the impressed current.

2.3.2 Pre-amplifier and Oscilloscope Requirements: The requirements for the performance of pre-amplifier and oscilloscope should be considered together. The more responsive one unit is, the less sensitivity is required of the other. Taken together, they should have the following characteristics:

a) Calibrated vertical deflection sensitivity of 2 cm/mv or better.
b) Vertical gain and deflection linear to within 3 per cent.
c) Rise time not more than 0.2 μsec.

In addition, the oscilloscope should:

d) Have a calibrated time base correct to 3 per cent and linear to within 3 per cent.
e) Be capable of being triggered by the signal being studied or by an external signal.
f) Be fitted with a reticule marked in centimeter squares on the back face (*i.e.*, the face nearest the CRT) on which is marked a curve, the height of which above the reticule base line decays exponentially with distance from the left, *i.e.*, $y=y_0 \exp(-x/L)$. Fig. 2 illustrates this, the curve (a) in the figure satisfying the equation $y=6 \exp(-x/2.5)$ with x and y in scale divisions.

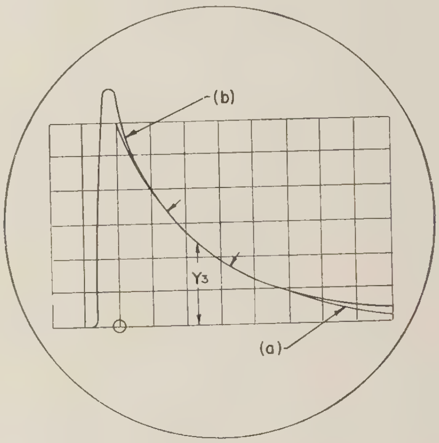

Fig. 2.

2.3.3 Suggested Measurement Procedure:

1) For reasonably small modulation (see Sections 2.2.1 and 2.4.2), the photoconductive signal voltage ΔV is proportional to the total number n of excess carriers in a filament. The mean volume concentration of excess carriers $\Delta\bar{n}$ through the affected region of the specimen is of course related to n by a simple geometric multiplying factor. Under these conditions the time constant of voltage decay τv equals τf, the time constant of excess carrier decay.
2) When illumination has ceased, τf is defined by the rate of decay of $\Delta\bar{n}$. Thus

$$(1/\tau f) = -(1/\Delta\bar{n})(d\Delta\bar{n}/dt) = -d(\ln \Delta\bar{n})/dt, \quad (8)$$

or

$$\Delta\bar{n} = A \exp(-t/\tau f). \quad (9)$$

3) The quantity τf need not be constant during a decay, and certainly will not be if there are recombination processes present for which the recombination rate does not vary linearly with the local excess carrier density. But in the *simple* case, τf does *not* depend on $\Delta\bar{n}$, and the decay exempli-

fied by (9) follows a pure exponential when higher-order modes of surface decay have become sufficiently attenuated.

4) The single time constant of a purely exponential photoconductive decay signal is to be measured by matching the decay of ΔV against the drawn exponential [curve (a)] of Fig. 2 on the oscilloscope face. The sequence of operations is as follows:

   a) Using a slow time sweep so that the screen width encompasses many lifetimes, the vertical shift control is adjusted to coincidence between the base line of the marker curve and base line of the decay itself.
   b) The time base is expanded to produce a decay trace similar to that of the marker (using either the signal itself or a separate synchronizing pulse to trigger the oscilloscope), and the horizontal shift, vertical amplification, and time-base-sweep speed controls are adjusted until the decay exactly matches the marker curve.
   c) If the decay *is* pure exponential, the match of decay and marker will be equally good when the vertical amplification is increased or decreased and the horizontal shift moved an appropriate amount to left or right. In making such a check, take care that no stage of the amplification system is driven into nonlinear conditions.
   d) If the marker curve is drawn to attenuate by a factor of $e=2.718$ in L cm, and the trace follows the same decay when the time base sweep is set at S_1 µsec/cm, then the filament lifetime is

$$\tau f = LS_1\ \mu\text{sec}. \tag{10}$$

5) It should be noted that the above procedure requires an oscilloscope for which the time base is continuously calibrated. However, many oscilloscopes have only a number of fixed calibrated sweep rates, the interpolated rates being uncalibrated. With such an instrument, proceed as follows:

   a) Carry out the steps described in 4)-a), -b), and -c) in order to verify that the decay *is* pure exponential.
   b) Turn the sweep speed to the nearest calibrated position, say S_2 µsec/cm. Measure the horizontal distance, say M cm between any two points on the decay whose amplitudes are in a ratio of 2:1. Then the filament lifetime is

$$\tau f = \frac{MS_2}{\ln 2} = 1.44MS_2\ \mu\text{sec}. \tag{11}$$

6) From (8) it is evident that in measuring lifetime we are measuring the logarithmic decay slope of $\Delta\bar{n}$. This is simple when τf is constant, for then the curve is a pure exponential which has the same logarithmic slope throughout. In many experimental cases, however, the logarithmic slope changes through the course of the decay, *i.e.*, τf is a function of $\Delta\bar{n}$. It is still possible to measure lifetime, but now the filament must be described by a series of pairs of values for τf and $\Delta\bar{n}$.

7) In the general case, then, a lifetime is determined from the slope and amplitude of decay at a single instant. This may be done by matching the decay rate at a given point to the decay rate of an exponential marker curve, as in Fig. 2. The two curves have identical slopes at a certain amplitude (say $y=y_3$) when the sweep speed is S_3 µsec/cm; thus

$$\tau f = LS_3\ \mu\text{sec}$$

for

$$y = y_3, \qquad \Delta\bar{n} = \Delta\bar{n}_3 \tag{12}$$

but there will be a finite region of the decay, indicated by a pair of arrows, for which the difference between the two curves is imperceptible. The more strongly τ depends on $\Delta\bar{n}$, the shorter will this region of apparent coincidence be, and the more important will it be to measure τf for a number of values of $\Delta\bar{n}$.

8) The procedure of Section 7) can be carried out only with an oscilloscope of continuously calibrated sweep. Using an instrument with only fixed calibrated points, it is necessary to adopt the procedure of Section 5) for any decay, whether pure exponential or not. This has the effect of measuring the *average logarithmic slope* of decay between points corresponding with an amplitude ratio of 2:1. When τ is a gradual function of Δn, the error involved in such a procedure is not large. But τ can be a rapid function of Δn in p-type silicon, and the error involved in taking such a wide range average may then be severe.

9) Even when the lowest mode of bulk and surface recombination is purely exponential in decay, higher modes will interfere in the early stages. Then ΔV will be a rapid function of t at first, approaching the behavior of the lowest mode as the decay proceeds. No measurement of the decay slope should be made until the signal has decayed to less than 60 per cent of the peak value if half or less of the width of the filament is exposed to illumination. On the other hand, if more than half the entire width of the specimen is illuminated, no measurement should be made until the signal is less than 25 per cent of the peak value.

2.4 Interpretation

2.4.1 Analysis of Nonexponential Decay: Often, in the case of silicon measurements, the decay curve will not consist of a single exponential. Three general cases can arise as follows:

A) Trapping (see Fig. 3). It may be determined whether the longer time constant for the final decay at room temperature is due to trapping, by heating the sample to 50–70°C and observing whether the long time constant disappears. If the tail does disappear with heating, one has trapping, and a reliable lifetime determination will not be possible by the present method. When trapping is present to no greater extent than 5 per cent of the total amplitude, a determination of lifetime can still be made by matching the exponential. A steady background light might also be used to test for traps, and this is perhaps simpler than the heating of the sample.

B) The initial part of the decay, representing usually less than 40 per cent of the amplitude, should be ignored, since it does not represent the true lifetime (see Fig. 4). The initial decay is a function mainly of higher modes associated with surface recombination.

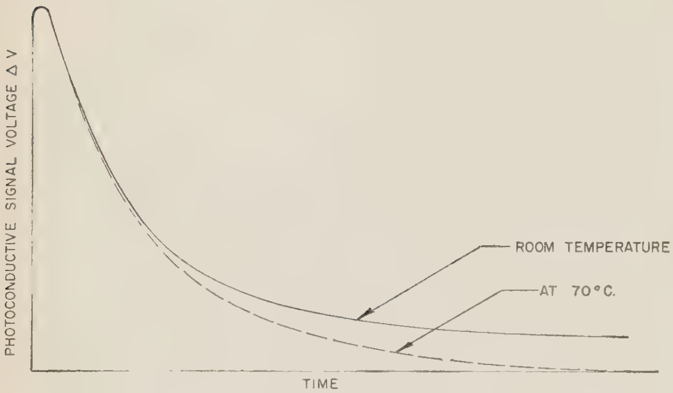

Fig. 3—Evidence of trapping.

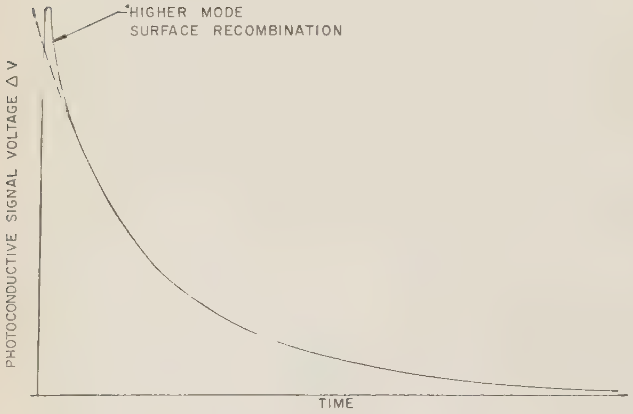

Fig. 4—Evidence of surface recombination.

C) In some cases, even after taking under consideration parts A) and B), it still will not be possible to match the decay curve to the simple exponential. (For example, τB is a function of Δn in p-type silicon.) One can, however, match a portion of the curve representing a particular concentration of excess carriers, which may be calculated from the amplitude as described below.

2.4.2 Evaluation when Modulation is Finite:

A) Relation of carrier and conductivity modulation to signal voltage: As remarked previously, the sample conductance and potential drop change by the same fractional amount in a constant-current circuit *if the modulation is very small.* For a finite (but not too large) modulation of carrier concentration, the change ΔV in voltage still can be related to the change in bulk conductivity. Thus, consider a sample of conductivity σ_0, in which by illuminating a fraction β of the width, the conductivity in that fraction is caused to increase to a mean value $(\sigma_0+\Delta\bar{\sigma})$. Then, if V_0 was the normal potential drop along the *illuminated* part of the sample length,

$$\Delta\bar{\sigma} = \frac{(\sigma_0)}{\beta}\cdot\frac{(\Delta V/V_0)}{1-(\Delta V/V_0)}, \qquad (\Delta V/V_0) \leq 0.1. \qquad (13)$$

Since σ_0 will customarily be measured on any sample prior to a lifetime determination, a given ΔV can be converted into the corresponding $\Delta\bar{\sigma}$. When trapping is absent, the relation

$$\Delta\bar{n} = \frac{\Delta\bar{\sigma}}{e(\mu_n+\mu_p)}, \qquad \Delta\bar{n} \leq \frac{n_0}{20} \text{ or } \frac{p_0}{20} \qquad (14)$$

may be used to go a stage further, and permit the mean volume concentration of excess carriers to be deduced from the conditions of the measurement.

Only when results of high precision are required is it necessary to use (13) rather than the simple limiting form for small modulation,

$$\Delta\bar{\sigma} = (\sigma_0/\beta)\cdot(\Delta V/V_0), \qquad (\Delta V/V_0) \ll 1. \qquad (15)$$

The assumption that an excess carrier will provide the same current impulse wherever it is created in a sample is only valid if the concentration of such carriers is everywhere small compared with the permanent majority-carrier concentration. Thus the preceding discussion requires that the majority-carrier concentration be modulated by not more than 5 per cent.

Indeed, measurement should not normally be made with a modulation anywhere near this large, unless there is a specific need to know τB for a certain excess pair density. In the characterization of bulk material, measurements involving very small departures from thermal equilibrium are usually most reproducible and, therefore, most useful.

B) Voltage- and carrier-decay coefficients for finite modulation: When measurements must be made for more than one per cent carrier-concentration modulation, not only should (13) be used rather than (15), but a distinction should also be made between the time constant of *voltage* decay $\tau v = -\Delta V(dt/d\Delta V)$ and the *filament* lifetime $\tau f = -\Delta \bar{n}(dt/d\Delta \bar{n})$. These two time constants are equal for very small modulation, but for finite modulation

$$\tau f = \tau v[1 - (\Delta V/V_0)]. \qquad (16)$$

The quantity experimentally determined is τv, but by using (16) it is a simple matter to obtain τf. The surface correction may then be applied to yield the volume lifetime

$$\tau B = [(1/\tau f) - \nu_s]^{-1}. \qquad (17)$$

APPENDIX

Data are given below for the three standard sample sizes:

Type	*Length*	*Cross Section*
A	1.5 cm	0.25×0.25 cm²
B	2.5	0.5 ×0.5
C	2.5	1.0 ×1.0

TABLE I

MAXIMUM MEASURABLE VALUES OF VOLUME LIFETIME τB

Sample	Type A	Type B	Type C
p-type Ge	32 μsec	125 μsec	460 μsec *
n-type Ge	64	250	950 *
p-type Si	90	350	1340
n-type Si	240	950	3600

TABLE II

SURFACE-RECOMBINATION RATE ν_s

Sample	Type A	Type B	Type C
p-type Ge	32,300 sec⁻¹	8130 sec⁻¹	2150 sec⁻¹
n-type Ge	15,750	3960	1050
p-type Si	11,200	2820	745
n-type Si	4,200	1050	279

The value of the maximum volume lifetime measurable for each of these sample sizes is given in Table I, and the corresponding surface recombination rate ν_s used to determine the maximum lifetime is given in Table II. The maximum value of lifetime here is set by the condition that τB should not be larger than $1/\nu_s$. When this condition is reached, $\tau f = \tau B/2 = 1/2\nu_s$. Thus, τf should not exceed half the value listed here for each specimen size. In the starred cases, it may be desirable to stretch the upper limit to 1000 μsec ($\tau f = 320$ μsec for *p*-type germanium, $\tau f = 490$ μsec for *n*-type germanium), recognizing that uncertainty in the surface term will have a greater effect on the final result. Values of $D_n = 101$, $D_p = 49$ cm²/sec for germanium, and $D_n = 35$, $D_p = 13.1$ cm²/sec for silicon were used in calculating the values given in Tables I and II.

Detection Range Predictions for Pulse Doppler Radar*

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Summary—**A mathematical model of sufficient flexibility to describe most pulse Doppler radar search systems is constructed and used to predict detection ranges. It is applicable to situations where thermal noise and/or sidelobe clutter limits detection range. The sidelobe clutter is assumed to be statistically similar to thermal noise. The model allows the variation of most of the important radar parameters. The receiver is assumed to have a number of rectangular, nonoverlapping range gates followed by narrow-band, Gaussian shaped Doppler filters, and then a square-law envelope detector followed by a postdetection filter consisting of one or two stages having exponential weighting functions. Single scan and cumulative probabilities of detection are calculated for both steady and scintillating targets.**

I. INTRODUCTION

ALTHOUGH the literature dealing with the performance of radar systems is extensive, there are only a few[1,2] treatments of pulse Doppler radar systems. The case of a "matched filter" radar has been analyzed by Siebert.[3] The object of this paper is to predict the detection capability of a pulse Doppler radar where the Doppler filter bandwidth is much wider than the bandwidth of each spectral line in the received signal.

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[1] J. J. Bussgang, P. Nesbeda, and H. Safran, "A unified analysis of range performance of CW, pulse, and pulse Doppler radar," PROC. IRE, vol. 47, pp. 1753–1762; October, 1959.

[2] E. J. Barlow, "Doppler radar," PROC. IRE, vol. 37, pp. 340–355; April, 1949.

[3] W. McC. Siebert, "A radar detection philosophy," IRE TRANS. ON INFORMATION THEORY, vol. IT-2, pp. 204–221; September, 1956.

Unlike those papers which use false alarm probabilities, this paper considers the false alarm rate as one of the fundamental design parameters. (The false alarm rate is proportional to the amplitude density of the noise,[4] whereas the false alarm probability is proportional to the cumulative probability density of the noise.) Moreover, this treatment introduces a mathematical model of sufficient flexibility to predict detection ranges for many pulse Doppler radar search systems. It is applicable to situations where thermal noise and/or sidelobe clutter limits detection range. The sidelobe clutter is assumed to be statistically similar to thermal noise. The model allows the variation of most of the important radar parameters. The antenna beam shape is assumed to be Gaussian; however, the scan speed and beamwidth remain general. The receiver is assumed to have a number of rectangular, nonoverlapping range gates, each followed by a multiplicity of Gaussian shaped Doppler filters. The number and width of gates and filters are left open. The output of the Doppler filter is passed through a square-law envelope detector followed by a postdetection filter consisting of one or two stages having exponential weighting functions. A block diagram of the radar receiver is found in Fig. 1.

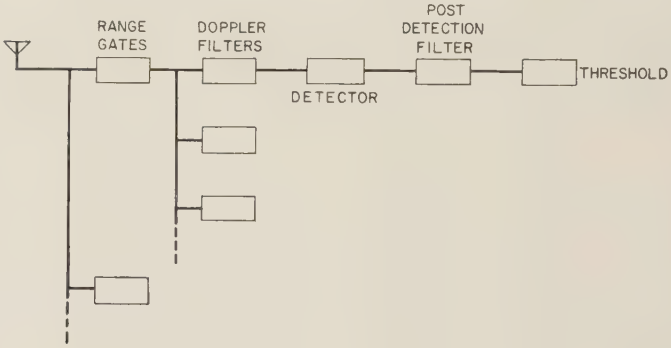

Fig. 1—Block diagram of a pulse Doppler receiver.

It is assumed that the received signal falls in the center of the Doppler filter. However, the power lost by not having the signal in the center of the filter becomes important only when the filter gain at the crossover becomes less than about 2 db. With this degree of overlap, the detection range does not change much with the frequency of the received signal.

The square-law envelope detector was selected for analysis mainly for mathematical convenience. Nevertheless, on the basis of a "Monte Carlo" simulation of the detection process on a digital computer,[5] the detection range with a linear envelope detector is not appreciably different from that of the square-law device. Marcum[6] has also found in his studies very little difference in results between linear and square-law detectors.

Single-scan detection probabilities are computed by calculating the probability that signal plus noise (or noise plus clutter) exceeds a threshold at the time for which the ensemble average of signal plus noise is maximum. The aforementioned "Monte Carlo" simulation indicates that the calculation of the probability of detection at the peak signal-to-noise ratio is an excellent approximation.

The model allows the target either to be steady or to scintillate slowly with a Rayleigh amplitude distribution; that is, the target cross section remains constant during the time on target but may vary randomly from scan to scan.

II. Detailed Calculations

A. Notation

A = amplitude of the received signal
f_c = carrier frequency of the received signal
t = time
Ψ = phase factor
W = pulse width
T = pulse repetition period
$g(t)$ = two-way voltage gain of the normalized antenna pattern
$\dot{\theta}$ = antenna scan rate
θ_{HP} = half-power beamwidth of the one-way antenna pattern
$s(t)$ = signal output of the Doppler filter
$n(t)$ = noise output of the Doppler filter
$x(t)$ = component of the noise
$y(t)$ = component of the noise
$E(t)$ = signal-plus-noise output of the Doppler filter
f = frequency
$W(f)$ = power spectrum of the noise
γ = noise power per cycle at the Doppler filter input

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[4] S. Thaler and S. A. Meltzer, "The amplitude distribution and false alarm rate of noise after post-detection filtering," Proc. IRE, vol. 49, pp. 479–485; February, 1961.

[5] Hughes Aircraft Co., Culver City, Calif., internal rept.

[6] J. I. Marcum, "A statistical theory of target detection by pulsed radar," IRE Trans. on Information Theory, vol. IT-6, pp. 59–144; April, 1960.

B = noise bandwidth of the Doppler filter
$U(t)$ = low-frequency output of the square-law detector
$V(t)$ = output of the postdetection filter
$h(t)$ = weighting function of the postdetection filter
τ_0 = time constant of the single low-pass postdetection filter
$J(t)$ = Signal-to-noise ratio (SNR) after the low-pass filter
$V_n(t)$ = noise output of the low-pass filter when there is no signal present
N = noise power after postdetection filtering
F = SNR in the Doppler filter
α = time on target
P_D = single-scan detection probability
α = threshold setting
K = number of range gates
D = range-gate width
P_C = cumulative probability of detection
F.A.R. = false-alarm rate per Doppler channel
M = expected number of positive crossings of the mean of the noise after postdetection filtering
$Q(\alpha)$ = probability density of the noise amplitude after postdetection filtering
$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_0^x e^{-t^2}{}_1/2dt.$

B. Output of the Doppler Filter

The signal at the receiver consists of a periodically pulsed, coherent sinusoid whose amplitude is modulated by the antenna pattern as the beam linearly sweeps the target and whose frequency differs from that of the transmitter by a Doppler shift. It is assumed at this point that the received pulse falls completely within the range gate and that the target is not scintillating. These restrictions will be removed in later sections of this paper. This signal can be represented as the product of a Doppler-shifted sinusoid

$$A \cos (2\pi_{fc}t + \Psi), \tag{1}$$

a pulsing function

$$\frac{W}{T} + \sum_{n=1}^{\infty} \frac{2}{n\pi} \sin \frac{n\pi W}{T} \cos 2\pi \frac{n}{T} t, \tag{2}$$

and an amplitude modulation proportional to the two-way voltage gain of the normalized antenna pattern, assumed to be Gaussian and denoted by $g(t)$,

$$g(t) = \exp\left[-\left(\frac{\dot{\theta}t}{\theta_{\text{HP}}}\right) 4 \ln 2\right] \tag{3}$$

where f_c is the carrier frequency of the received signal, W is the pulse width, T is the pulse repetition period, θ is the antenna scan rate, θ_{HP} is the half-power beamwidth of the antenna one-way power pattern, and the target is on the peak of the beam at time $t=0$.

If it is assumed that the width of the Doppler filter is such that only the center line of the received spectrum (along with the modulation sidebands due to the antenna pattern) is passed, the output of the Doppler filter, denoted by $s(t)$, is

$$s(t) = \frac{AW}{T} \exp\left\{-\left(\frac{\dot{\theta}t}{\theta_{\text{HP}}}\right)^2 4 \ln 2\right\} \cos(2\pi f_c t + \Psi). \tag{4}$$

This result also assumes that the Doppler filter is wide compared to the bandwidth of each spectral line in the received signal. If this assumption is not true (4) must be modified accordingly.

The output of the Doppler filter also includes noise, $n(t)$, and/or clutter. Since the clutter is assumed to be statistically similar to random noise, it will merely be necessary to study the case where noise alone is present, and then to modify the results to account for the clutter. The total Doppler-filter output is the sum of signal and noise, which is denoted by $E(t)$.

$$E(t) = s(t) + n(t). \tag{5}$$

The process $n(t)$, which consists of white Gaussian noise, passed through the Doppler filter, is assumed to be stationary and ergodic. Narrow-band noise can be represented by[7]

$$n(t) = x(t) \cos 2\pi f_c t - y(t) \sin 2\pi f_c t, \tag{6}$$

where $x(t)$ and $y(t)$ are independent Gaussian processes with zero means and equal variances. It is assumed that the center of the Doppler filter is at f_c and that the filter is Gaussian in shape. Thus, the power spectrum of the noise is

$$W(f) = \frac{\gamma}{2} \left[e^{-(\pi(f-f_c)^2)/B^2} + e^{-(\pi(f+f_c)^2)/B^2)}\right], \tag{7}$$

where B is the noise bandwidth of the Doppler filter and γ is the noise power per cycle at its input. The average noise power out of the Doppler filter is equal to γB.

$$\begin{aligned} E(t) = {} & \frac{AW}{T} g(t) \cos(2\pi f_c t + \Psi) \\ & + x(t) \cos 2\pi f_c t - y(t) \sin 2\pi f_c t. \end{aligned} \tag{8}$$

C. Low-Frequency Output of the Square-Law Detector

The square-law detector is followed by a low-pass filter, so the high-frequency output of the square-law device will be filtered out. The low-frequency output, denoted by $U(t)$, is

$$\begin{aligned} U(t) = \frac{1}{2}\bigg\{ & \frac{A^2W^2}{T^2} g^2(t) + x^2(t) + y^2(t) \\ & + \frac{2AW}{T} g(t)[x(t) \cos \Psi + y(t) \sin \Psi]\bigg\} \end{aligned} \tag{9}$$

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[7] S. O. Rice, "Mathematical analysis of radar noise," *Bell Sys. Tech. J.*, vol. 24, p. 75; January, 1945.

D. Output of the Postdetection Filter

The output of the postdetection filter, denoted by $V(t)$, is

$$V(t) = \int_{-\infty}^{t} h(t-\tau)U(\tau)d\tau, \qquad (10)$$

where $h(t)$ is the filter weighting function, or impulsive response.

Two weighting functions for the postdetection filter will be considered. The first is assumed to be exponential.

$$h_1(t) = \begin{cases} \dfrac{1}{\tau_0} e^{-t/\tau_0} & 0 \le t \\ 0 & 0 > t. \end{cases} \qquad (11)$$

τ_0 is the time constant of the filter. The output of this filter, $V_1(t)$, is

$$V_1(t) = \int_{-\infty}^{t} \frac{1}{\tau_0} e^{-(t-\tau)/\tau_0} U(\tau)d\tau. \qquad (12)$$

The second weighting function is obtained by cascading two filters, each having an exponential weighting function. The resulting weighting function is

$$h_2(t) = \begin{cases} \dfrac{t}{\tau_0^2} e^{-t/\tau_0} & 0 \le t \\ 0 & 0 > t. \end{cases} \qquad (13)$$

The filter output, $V_2(t)$, is

$$V_2(t) = \int_{-\infty}^{t} \frac{(t-\tau)}{\tau_0^2} e^{-(t-\tau)/\tau_0} U(\tau)d\tau. \qquad (14)$$

E. The Time Constant of the Postdetection Filter

The signal-to-noise ratio after the postdetection filter, designated by the symbol $J(t)$ will be defined as the ratio of the increase in the expected value of the filter output when signal is present to the standard deviation of the noise fluctuations out of the filter with no signal present.

$$J(t) = \frac{\langle V \rangle - \langle V_n \rangle}{[\langle V_n^2 \rangle - \{\langle V_n \rangle\}^2]^{1/2}}, \qquad (15)$$

where $V_n(t)$ is the output of the low-pass filter when there is no signal present.

The notation $\langle\ \rangle$ indicates the ensemble average of the quantity enclosed. The ensemble averages of V_n and V_n^2 are assumed to be independent of time. However, the ensemble average of signal plus noise, $\langle V \rangle$, is a function of time. To simplify future equations, let $\langle V_n^2 \rangle$, the noise power out of the postdetection filter, be denoted by N. The value of the filter time constant will be selected to maximize this SNR.

1. *Single Low-Pass Filter:* From (12) and (39) it is seen that

$$\langle V_1(t) \rangle = \gamma B + \frac{A^2W^2}{2\tau_0 T^2} \int_{-\infty}^{t} e^{-(t-\tau)/\tau_0} g^2(\tau)d\tau, \qquad (16)$$

and

$$\langle V_n(t) \rangle = \gamma B. \qquad (17)$$

The value of N_1 is given by equation (50). The SNR, $J_1(t)$, is

$$J_1(t) = \frac{2^{3/4}B^{1/2}F}{\tau_0^{1/2}} \int_{-\infty}^{t} e^{-(t-\tau)/\tau_0} g^2(\tau)d\tau \qquad (18)$$

where F, the SNR in the Doppler filter, is defined by

$$F = \frac{A^2W^2}{2T^2\gamma B}. \qquad (19)$$

The SNR at the output of the single low-pass filter, $J_1(t)$, considered as a function of τ_0 and t, takes on its maximum value at $\tau_0 = 0.62a$ and $t = 0.31a$. The symbol a stands for the time on target defined by

$$a = \frac{\theta_{HP}}{\dot{\theta}}. \qquad (20)$$

This maximum value is

$$J_1 = 0.77B^{1/2}a^{1/2}F. \qquad (21)$$

2. *Cascaded Low-Pass Filter:* From (14) and (39) it is seen that

$$\langle V_2(t) \rangle = \gamma B + \frac{A^2W^2}{2\tau_0^2 T^2} \int_{-\infty}^{t} (t-\tau)e^{-(t-\tau)/\tau_0} g^2(\tau)d\tau. \qquad (22)$$

The value of N_2 is found from (53). The SNR $J_2(t)$ is

$$J_2(t) = \frac{2^{5/4}B^{1/2}F}{\tau_0^{3/2}} \int_{-\infty}^{t} (t-\tau)e^{-(t-\tau)/\tau_0} g^2(\tau)d\tau. \qquad (23)$$

$J_2(t)$ takes on its maximum value for $\tau_0 = 0.29a$ at $t = 3/2\tau_0$. The maximum value of the SNR is

$$J_2 = 0.84B^{1/2}a^{1/2}F. \qquad (24)$$

F. Probability of Detection

The single-scan probability of detection calculated at the instant of time at which the SNR out of the postdetection filter is maximum will be denoted by P_D. The event of detection will be said to have occurred if the output of the postdetection filter exceeds the threshold setting in the threshold device. The detection probability during the time interval when the output SNR is near its peak value can be obtained by making the very reasonable assumption that the amplitude statistics of the output of the low-pass filter are approximately Gaussian. Let the threshold setting be given by a constant α times the standard deviation of the noise fluctuations out of the low-pass filter when no signal is present. Then from (21) and (61), the probability of detection for the system having the single low-pass filter is

$$P_D(F) = \frac{1}{2} - \Phi\left\{\frac{\alpha - 0.77B^{1/2}a^{1/2}F}{(1 + 2.12F)^{1/2}}\right\}. \qquad (25)$$

It is to be noted that the threshold setting α is measured from the mean noise level out of the postdetection filter when no signal is present. Eqs. (24) and (64) are utilized to determine the probability of detection for the system having the cascaded low-pass filter.

$$P_D(F) = \frac{1}{2} - \Phi\left\{\frac{\alpha - 0.84B^{1/2}a^{1/2}F}{(1 + 2.22F)^{1/2}}\right\}. \qquad (26)$$

Eqs. (25) and (26) yield the single-scan probability of detection for the case where the pulse train received from the target suffers no degradation due to obscuring by the transmitter or by straddling of the range gates. Furthermore, (25) and (26) hold only for a nonscintillating target. It is not difficult to modify these equations to remove these restrictions.

1. *Range Gating:* For the purpose of this calculation, the following assumptions are made:

1) The receiver has K nonoverlapping range gates, each of time duration D.
2) The relative time of reception of pulses within a range gate does not alter during the on-target period.
3) From scan to scan, the reception of the pulse train will commence with equal probability anywhere within the interval between pulses (pulse repetition period).

It is further assumed that

$$D \geq W, \qquad (27)$$

where W is the pulse width and D the gate width. Eq. (19) shows that the SNR, F, is proportional to W^2. Thus, the probability of detection averaged over all possible reception times of the received pulse train within a pulse repetition period, denoted by $\overline{P_D(F)}$, is

$$\overline{P_D(F)} = K\left(\frac{D}{T} - \frac{W}{T}\right)P_D(F) + 2\frac{W}{T}\int_0^1 P_D(x^2F)dx$$
$$+ (K-1)\frac{W}{T}\int_0^1 P_D(x^2F)[2 - P_D\{(1-x)^2F\}]dx. \qquad (28)$$

The first term in (28) accounts for the return pulse being completely within the range gate; the second term accounts for the effect of its straddling the leading edge of the first gate or the trailing edge of the Kth gate; and the third term accounts for its straddling the boundary between two gates. Thus, for a nonscintillating target, the single-scan probability of detection for the system having the single low-pass filter is found by combining (25) and (28), and the probability of detection for the system having the cascaded low-pass filter is found by combining (26) and (28).

2. *Target Scintillation:* The case of slow scintillation—that is, when the cross section remains constant during the time on target but may vary randomly from scan to scan—will be considered here. We will assume that the radar cross section, which is directly proportional to F, is exponentially distributed. (This implies that the envelope statistics of the target return is Rayleigh distributed.) Then the single-scan probability of detection, averaged over the target's scintillation and denoted by $\langle\overline{P_D(F)}\rangle$, is

$$\langle\overline{P_D(F)}\rangle = \int_0^\infty e^{-y}\,\overline{P_D(yF)}\,dy. \qquad (29)$$

3. *Cumulative Probability of Detection:* Let the cumulative probability of detection at the nth scan be defined as the probability that the target has been detected at least once by the nth scan. Then the cumulative probability of detection is given by

$$P_C^{(n)} = P_C^{(n-1)} + [1 - P_C^{(n-1)}]P_D^{(n)}, \qquad (30)$$

where

$P_C^{(n)}$ is the cumulative probability of detection and
$P_D^{(n)}$ is the single-scan probability of detection for the nth scan.

G. False Alarm Rate

An extensive study[4] has been carried out on an IBM 709 to determine the false-alarm rate for the detector and postdetection filtering assumed in this paper. It was concluded that the false-alarm rate (F.A.R) could be represented by

$$\text{F.A.R.} = \frac{MQ(\alpha)}{Q(0)}, \qquad (31)$$

where M is the expected number per second of positive crossing of the mean of the noise out of the postdetection filter, Q is the probability density of this noise amplitude, and α is the threshold level, measured from the mean output in standard deviations of the noise out of the postdetection filter. The above formula holds in the region where false alarms are relatively rare, *i.e.*, much less than one false alarm during the time on target. Rice's[8] formula for Gaussian noise for the expected number of positive crossings of a threshold is the same form as (31).

Explicit expressions for M have been derived in Appendix IV. If these expressions are evaluated for the optimum time constants for the respective postdetection filters, it is found that

$$M_1 = 0.34(B/a)^{1/2} \qquad (32)$$

for the single low-pass filter, and

$$M_2 = \frac{0.55}{a} \qquad (33)$$

for the cascaded low-pass filter. $Q(\alpha)$ is graphed for each postdetection filter in Figs. 2 and 3, respectively.

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[8] S. O. Rice, "Mathematical analysis of random noise," *Bell Sys. Tech. J.*, vol. 24, p. 55; Eqs. 3.3–14; January, 1945.

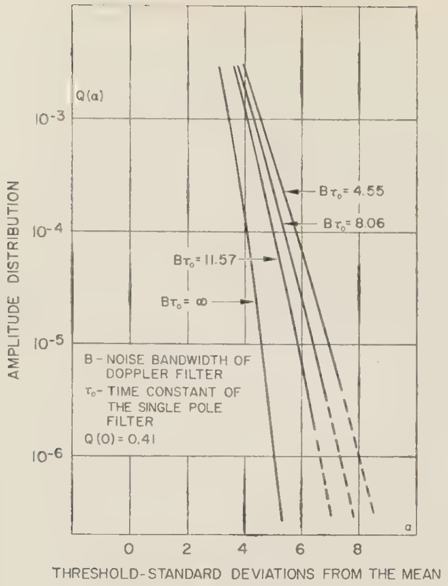

Fig. 2—Amplitude distribution after postdetection filtering (square-law detector, single-pole filter).

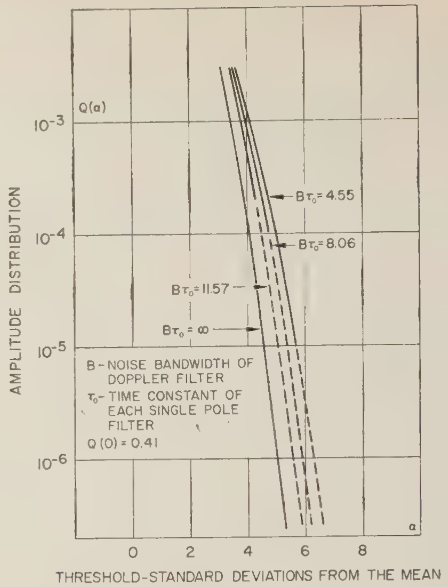

Fig. 3—Amplitude distribution after postdetection filtering (square-law detector, double-pole filter).

III. Detection Range Predictions

The system parameters in conjunction with the radar range equation can be used to calculate the SNR in the Doppler filter. Denoting this SNR by F [refer to (19)], we have

$$F = \frac{P_{\text{av}}(W/T)G_0^2\lambda^2\bar{\sigma}L}{(4\pi)^3(D/T)kT_EBR^4}, \qquad (34)$$

where

P_{av} = average transmitter power
W = transmitted pulse width
T = pulse repetition period
G_0 = antenna axial gain (one-way)
λ = carrier wavelength
$\bar{\sigma}$ = mean target cross section
L = real system losses (plumbing, radome, atmospheric attenuation)
D = time duration of the range gate
k = Boltzmann's constant (1.38×10^{-23} joules per degree Kelvin)
T_E = effective noise temperature of the receiver in degrees Kelvin
B = noise bandwidth of Doppler filter
R = range.

The range at which the value of F is unity is denoted by R_0.

$$R_0 = \left[\frac{P_{\text{av}}(W/T)G_0^2\lambda^2\bar{\sigma}L}{(4\pi)^3(D/T)kT_EB}\right]^{1/4} \qquad (35)$$

Thus it follows that

$$F = \left[\frac{R_0}{R}\right]^4 \qquad (36)$$

In the sidelobe clutter region, the only modification to the detection theory is that R_0 must be modified to

$$R_0 = \left\{\frac{P_{\text{av}}(W/T)G_0^2\lambda^2\bar{\sigma}L}{(4\pi)^3[C + (D/T)kT_EB]}\right\}^{1/4} \qquad (37)$$

where C is the clutter power after Doppler filtering.

The single-scan probability of detection as a function of range is computed from (28) and (29), or from (28) alone, depending on whether the target is slowly scintillating or nonscintillating. These equations require as an input either (25) or (26), depending on the type of postdetection filter. A new input equation would be required for types of postdetection filters not covered in this paper. The relationship between the radar parameters and the range is given by (35) and (37). The cumulative probability of detection as a function of range is found from (30). These computations require the specification of the following parameters:

1) Time on target (a), determined from (20).
2) Doppler filter noise bandwidth (B).
3) Number of range gates (K).
4) Transmitter duty factor (W/T).
5) Range-gate duty factor (D/T).
6) Initial range separation between target and interceptor (R_I).
7) Threshold setting (α), determined from (31) and Figs. 2 and 3.
8) The range at which the signal-to-noise (or noise-plus-clutter) ratio in the Doppler filter equals unity (R_0), determined from (35) and (37).
9) Change in range between scans (ΔR). For a collision course, the change in range between scans, ΔR, equals the product of range closing rate and scan time.

Because of the complicated form of (28) required to account for range-gate straddling and eclipsing by the

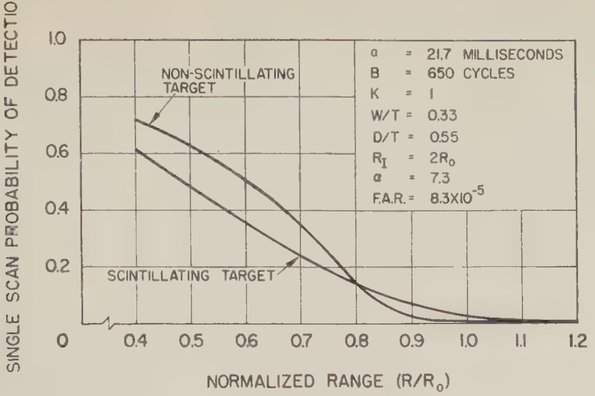

Fig. 4—Single-scan probability of detection (square-law detector, single-pole filter).

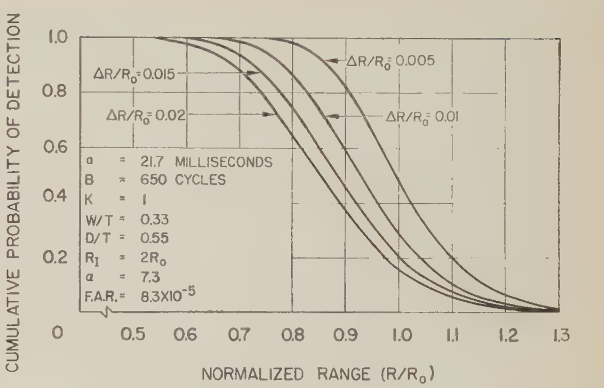

Fig. 5—Cumulative probability of detection of a scintillating target (square-law detector, single-pole filter).

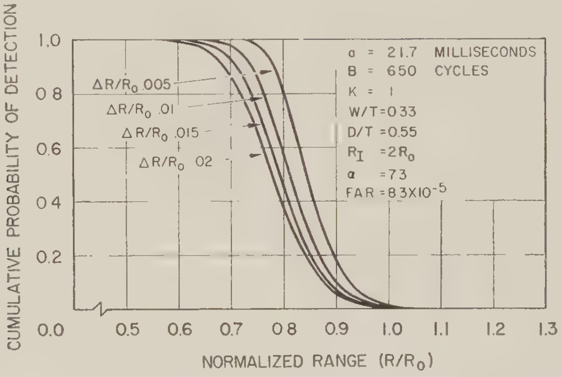

Fig. 6—Cumulative probability of detection of a nonscintillating target (square-law detector, single-pole filter).

transmitter of the received signal, it was found necessary to program these equations for a computer.

Once the false-alarm rate per Doppler channel has been specified, (31) and (32) or (33) enable one to calculate the numerical value of $Q(\alpha)$, the probability density of the noise after postdetection filtering, required to give that false-alarm rate. Fig. 2 or 3 is then used to yield the appropriate value of α, the threshold setting. These figures contain plots of the amplitude distribution of the noise after postdetection filtering vs α, the threshold setting, for four different ratios of predetection-to-postdetection bandwidth. In most cases, it is necessary to interpolate between these curves to determine the appropriate value of α. Typical results obtained by using this detection model are graphed in Figs. 4–6. Graphs of results for the cascaded postdetection filter have been omitted since this filter provides less than 1 db improvement in performance.

Appendix I

Low-Frequency Noise Power Spectrum Out of the Square-Law Detector

It is seen from (9) that if no signal is present, the low-frequency noise out of the detector, denoted by $n_0(t)$, is

$$n_0(t) = \tfrac{1}{2}\left[x^2(t) + y^2(t)\right]. \tag{38}$$

The correlation function of $n_0(t)$ is designated $R(\tau)$. By definition,

$$\langle x(t)x(t+\tau)\rangle = \langle y(t)y(t+\tau)\rangle = \gamma B\rho(\tau) \tag{39}$$

where $\rho(\tau)$ is the normalized correlation function. Further, since x and y are independent Gaussian processes,

$$\begin{aligned}\langle x^2(t)x^2(t+\tau)\rangle &= \langle y^2(t)y^2(t+\tau)\rangle \\ &= (\gamma B)^2[1 + 2\rho^2(\tau)]\end{aligned} \tag{40}$$

from which it follows that

$$R(\tau) = \langle n_0(t)n_0(t+\tau)\rangle = (\gamma B)^2[1 + \rho^2(\tau)]. \tag{41}$$

Using (6) and (7), we can easily show that

$$\rho(\tau) = e^{-\pi B^2\tau^2}. \tag{42}$$

Representing the low-frequency power spectrum of the noise out of the detector by $N(f)$, we have

$$N(f) = (\gamma B)^2 \int_{-\infty}^{\infty} \left[1 + e^{-2\pi B^2\tau^2}\right] \cos 2\pi f\tau d\tau. \tag{43}$$

This equals

$$N(f) = (\gamma B)^2 \left[\delta(f) + \frac{1}{\sqrt{2}\,B} e^{-\pi f^2/2B^2}\right] \tag{44}$$

APPENDIX II

NOISE POWER OUT OF THE POSTDETECTION FILTER

It can be shown that the noise power out of the postdetection filter, denoted by N, is equal to

$$N = \int_{-\infty}^{\infty} | Y(f) |^2 N(f) df \tag{45}$$

where $Y(f)$, the filter frequency response function, is the Fourier transform of the filter weighting function.

$$Y(f) = \int_{-\infty}^{\infty} h(\tau) e^{i2\pi f\tau} d\tau. \tag{46}$$

A. Single Low-Pass Filter

The exponential weighting function is given by (11).

$$Y_1(f) = \int_0^{\infty} \frac{1}{\tau_0} e^{-\tau/\tau_0} e^{i2\pi f\tau} d\tau. \tag{47}$$

Thus,

$$| Y_1(f) |^2 = \frac{1}{1 + 4\pi^2 f^2 \tau_0^2} \cdot \tag{48}$$

Using (44) and (48), the noise power, N_1, out of the single low-pass filter is given by

$$N_1 = (\gamma B)^2 \int_{-\infty}^{\infty} \frac{1}{1 + 4\pi^2 f^2 \tau_0^2} \cdot \left\{ \delta(f) + \frac{1}{\sqrt{2}\, B} e^{-\pi f^2/2B^2} \right\} df. \tag{49}$$

Integrating equation (49) and assuming that $4\pi B^2 \tau_0^2 \gg 1$, we get

$$N_1 = (\gamma B)^2 \left\{ 1 + \frac{1}{2\sqrt{2} B\tau_0} \right\} \tag{50}$$

B. Cascaded Low-Pass Filter

The weighting function of this filter is given by (13). The frequency response function of this filter is the square of that for the single low-pass filter. Thus,

$$| Y(f) |^2 = \frac{1}{[1 + 4\pi^2 f^2 \tau_0^2]^2} \cdot \tag{51}$$

By use of (44), the noise power, N_2, out of the cascaded low-pass filter is

$$N_2 = (\gamma B)^2 \int_{-\infty}^{\infty} \frac{1}{[1 + 4\pi^2 f^2 \tau_0^2]^2} \cdot \left\{ \delta(f) + \frac{1}{\sqrt{2} B} e^{-\pi f^2/2B^2} \right\} df. \tag{52}$$

Integrating (52) and assuming that $4\pi B^2 \tau_0^2 \gg 1$, we get

$$N_2 = (\gamma B)^2 \left\{ 1 + \frac{1}{4\sqrt{2} B\tau_0} \right\} \cdot \tag{53}$$

APPENDIX III

STANDARD DEVIATION OF THE FLUCTUATIONS OF SIGNAL WITH NOISE OUT OF THE POSTDETECTION FILTER

A. Single Low-Pass Filter

The output of the single low-pass filter, $V_1(t)$, is given by (12). The variance of $V_1(t)$ is equal to

$$\text{Var } V_1(t) = \langle [V_1(t) - \langle V_1(t) \rangle]^2 \rangle. \tag{54}$$

The value of $\langle V_1(t) \rangle$ is found from (16). It can easily be seen, by means of (39) and (40), that

$$\text{Var } V_1(t) = \frac{(\gamma B)^2}{\tau_0^2} \int_{-\infty}^{t} \int_{-\infty}^{t} e^{-(t-\tau_1)/\tau_0} e^{-(t-\tau_2)/\tau_0} \cdot \left\{ \rho^2(\tau_2 - \tau_1) + 2F\rho(\tau_2 - \tau_1) g(\tau_1) g(\tau_2) \right\} d\tau_2 d\tau_1. \tag{55}$$

For reasons that will become apparent in the next section, it will be convenient to compute the following integral:

$$H(r, s) = \int_{-\infty}^{t} \int_{-\infty}^{t} e^{-r(t-\tau_1)/\tau_0} e^{-s(t-\tau_2)/\tau_0} \cdot \left\{ \rho^2(\tau_2 - \tau_1) + 2F\rho(\tau_2 - \tau_1) g(\tau_1) g(\tau_2) \right\} d\tau_2 d\tau_1. \tag{56}$$

It is evident that

$$\text{Var } V_1(t) = \frac{(\gamma B)^2}{\tau_0^2} H(1, 1). \tag{57}$$

We make the substitution $x = \tau_2 + \tau_1$ and interchange the order of integration in (56) to obtain

$$H(r, s) = \frac{\tau_0}{r + s} \int_0^{\infty} [e^{-rx/\tau_0} + e^{-sx/r_0}] \rho^2(x) dx + \frac{\sqrt{2\pi}\, aF}{2\sqrt{\ln 2}} e^{-(r+s)t/\tau_0} e^{-a^2(r+s)^2/32\tau_0^2 \ln 2} \cdot \int_0^{\infty} [e^{(r-s)x/2\tau_0} + e^{-(r-s)x/2\tau_0}] \left[\frac{1}{2} + \Phi\left(\frac{4t\sqrt{\ln 2}}{a} - \frac{2x\sqrt{\ln 2}}{a} - \frac{a(r+s)}{4\tau_0\sqrt{\ln 2}} \right) \right] e^{-2x^2 \ln 2/a^2} \rho(x) dx. \tag{58}$$

We replace

$$\frac{1}{2} + \Phi\left(\frac{4t\sqrt{\ln 2}}{a} - \frac{2x\sqrt{\ln 2}}{a} - \frac{a(r+s)}{4\tau_0\sqrt{\ln 2}} \right)$$

by its Maclaurin's series in x, integrate using the definition of $\rho(x)$ given by (42), and assume that $4\pi B^2 \tau_0^2 \gg 1$. Thus, we obtain

$$H(r, s) = \frac{\tau_0}{\sqrt{2}(r + s)B} + \frac{\sqrt{2\pi}\, aF}{2B\sqrt{\ln 2}} e^{-(r+s)t/\tau_0 + (r+s)^2 a^2/32\tau_0^2 \ln 2} \cdot \left[\frac{1}{2} + \Phi\left(\frac{4t\sqrt{\ln 2}}{a} - \frac{a(r+s)}{4\tau_0\sqrt{\ln 2}} \right) \right] \cdot \tag{59}$$

By combining (57), (59), (50) and (17), we have

$$\frac{\mathrm{Var}\, V_1(t)}{N_1 - \langle V_0(t)\rangle^2} = 1 + \frac{4\sqrt{\pi}aF}{2\tau_0\sqrt{\ln 2}}\, e^{-2t/\tau_0 + a^2/8\tau_0^2 \ln 2} \left[\frac{1}{2} + \Phi\left(\frac{4t\sqrt{\ln 2}}{a} - \frac{a}{2\tau_0\sqrt{\ln 2}}\right)\right]. \tag{60}$$

Evaluating (60) for $t=\tau_0/2$ and $\tau_0=0.62a$ results in

$$\frac{\mathrm{Var}\,(0.31a)}{N_1 - \langle V_0(t)\rangle^2} = 1 + 2.12F. \tag{61}$$

B. *Cascaded Low-Pass Filter*

The output of the cascaded low-pass filter is given by (14). The value of $\langle V_2(t)\rangle$ is given by (22). It can easily be seen, by means of (39) and (40), that

$$\begin{aligned}\mathrm{Var}\, V_2(t) &\\ = \frac{(\gamma B)^2}{\tau_0^4} &\int_{-\infty}^{t}\int_{-\infty}^{t} (t-\tau_1)(t-\tau_2)e^{-(t-\tau_1)/\tau_0}e^{-(t-\tau_2)/\tau_0} \\ &\cdot\left\{\rho^2(\tau_2-\tau_1) + 2F\rho(\tau_2-\tau_1)g(\tau_1)g(\tau_2)\right\}d\tau_2 d\tau_1.\end{aligned} \tag{62}$$

But this equals

$$\mathrm{Var}\, V_2(t) = \frac{(\gamma B)^2}{\tau_0^2}\left.\frac{\partial H(r,s)}{\partial r\partial s}\right|_{r=s=1}. \tag{63}$$

Combing (59), (63), (53), and (17) and setting $t=3/2\tau_0$ and $\tau_0=0.29a$ yields

$$\frac{\mathrm{Var}\, V_2(0.435a)}{N_2 - \langle V_0(t)\rangle^2} = 1 + 2.22F. \tag{64}$$

Appendix IV

Positive Crossing of the Mean of the Noise Process out of the Postdetection Filter

It can be seen from Rice[9] that the expected number per second of positive crossings of the mean of a Gaussian process is given by

$$M = \left[\frac{\int_0^\infty f^2 L(f)df}{\int_0^\infty L(f)df}\right]^{1/2} \tag{65}$$

where M is the expected number of crossings per second and $L(f)$ is the power spectrum (excluding the dc component) of the noise. In the case of the output of the postdetection filter, the amplitude density of the noise process deviates from the Gaussian only in the tails of the distribution. It will be of interest to compute (65) for the noise out of the postdetection filter.

A. *Single Low-Pass Filter*

Using (44) and (48), it is found that

$$L_1(f) = \frac{(\gamma B)^2}{\sqrt{2}B(1+4\pi^2 f^2\tau_0^2)}\, e^{-\pi f^2/2B^2}. \tag{66}$$

Defining

$$\Gamma_1(\lambda) = \int_0^\infty \frac{1}{(1+4\pi^2 f^2\tau_0^2)}\, e^{-\lambda\pi f^2/2B^2}df, \tag{67}$$

it is clear that

$$M_1 = \left[-\frac{2B^2}{\pi}\left.\frac{\partial \ln \Gamma_1(\lambda)}{\partial\lambda}\right|_{\lambda=1}\right]^{1/2}. \tag{68}$$

Integrating (67),

$$\Gamma_1(\lambda) = \frac{1}{2\tau_0}\, e^{\lambda/8\pi B^2\tau_0}\left\{\frac{1}{2} - \Phi\left(\frac{\sqrt{\lambda}}{2\sqrt{\pi}\, B\tau_0}\right)\right\} \tag{69}$$

Substituting (69) into (68) and assuming that

$$4\pi B^2\tau_0^2 \gg 1, \tag{70}$$

we get

$$M_1 = \frac{0.671B^{1/2}}{(2\pi\tau_0)^{1/2}}. \tag{71}$$

B. *Cascaded Low-Pass Filter*

By use of (44) and (51), it is seen that

$$L_2(f) = \frac{(\gamma B)^2}{\sqrt{2}B(1+4\pi^2 f^2\tau_0^2)^2}\, e^{-\pi f^2/2B^2}. \tag{72}$$

When we define

$$\Gamma_2(\lambda) = \int_0^\infty \frac{1}{(1+4\pi^2 f^2\tau_0^2)^2}\, e^{-\lambda\pi f^2/2B^2}df, \tag{73}$$

it is clear that

$$M_2 = \left[\frac{-2B^2}{\pi}\left.\frac{\partial \ln \Gamma_2(\lambda)}{\partial\lambda}\right|_{\lambda=1}\right]^{1/2}. \tag{74}$$

Integrating (73), we get

$$\Gamma_2(\lambda) = \left[\frac{1}{4\tau_0} - \frac{\lambda}{16\pi B^2\tau_0^3}\right]\left[\frac{1}{2} - \Phi\left(\frac{\sqrt{\lambda}}{2\sqrt{\pi}B\tau_0}\right)\right]e^{\lambda/8\pi B^2\tau_0^2} + \frac{\sqrt{\lambda}}{8\sqrt{2\pi}B\tau_0^2}. \tag{75}$$

Substituting (75) into (74) and assuming equation (70), we get

$$M_2 = \frac{1}{2\pi\tau_0}. \tag{76}$$

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[9] S. O. Rice, "Mathematical analysis of random noise," *Bell Sys. Tech. J.*, vol. 24, pp. 54–55; January, 1945.

Low-Level Garnet Limiters*

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Summary—*S*- and *L*-band low-level passive limiters preselectors using polished single crystals of narrow line-width yttrium-iron-garnet have been developed. The *S*-band limiter employed unsubstituted YIG and has an insertion loss of 0.6 db, a limiting threshold of −26 dbm, and a dynamic range greater than 30 db.

The *L*-band limiter used specially grown gallium-substituted YIG crystals, which, when ground into spheres and polished to a high finish, exhibited extremely narrow line widths. The *L*-band limiter had an insertion loss of 1.1 db, a limiting threshold of −21 dbm, and a dynamic range greater than 25 db. A tuning range from 1120 to 1305 Mc was obtained. Data on frequency sensitivity and SWR are given and indicate that such limiters have a high off-band rejection and a fair power-handling capability. A leading-edge spike of 0.1-μsec duration was observed.

The decline of the various components of the magnetic susceptibility tensor can be used to construct other novel types of limiters. The operation of three such devices—electronically-tunable preselectors, and cavity-type and comb-type limiters—will be described and experimental data given.

I. INTRODUCTION

FOR a long time there has existed a need for a microwave limiter which would protect microwave receivers against overload and burnout. In addition, requirements exist for microwave power levelers which eliminate power output variations in microwave power sources and in systems. Such limiters should preferably be passive and phase-distortionless. This paper discusses such limiter devices employing single crystals of unsubstituted and gallium-substituted yttrium-iron garnet as nonlinear elements. Limiters have been developed for *L* and *S* bands which have exceedingly low-limiting levels.

II. NONLINEARITY IN FERRITES

Experiments had shown that nonlinear effects appeared in ferrites at power levels only about 1 per cent of the level predicted by the simple saturation theory.[1,2] The main resonance line decreases in amplitude and broadens as the power level is increased. An additional rather broad absorption peak appears—usually at a value of applied static magnetic field, (H_z) lower than that required for the main resonance. This latter absorption has been called the subsidiary resonance.

The above effects have been explained by Suhl.[3,4] The decline of the main (uniform precessional) resonance is due to the excitation within the ferrite medium of z-directed spin waves at the same frequency as the driving-signal frequency. The appearance of the subsidiary absorption peak involves the parametric excitation of non-z-directed spin waved near one half the driving-signal frequency. These spin waves can be thought of as spatial disturbances in the normally uniform ferrite magnetization that propagate as plane waves through the medium. As the RF magnetic field is increased beyond an often sharply-defined critical level, the parametric coupling to these half-frequency spin waves increases, so that a subsidiary absorption peak will occur that increases with increasing signal level.

Thus, a limiter can be constructed in which the ferrite is placed in a coaxial line or waveguide, and the magnetic field is biased to an optimum value below resonance. Such subsidiary-resonance limiters have been investigated at *X*-band by Soohoo[5] and Uebele.[6]

For certain combinations of signal frequencies, ferrite geometry, and saturation magnetization, the range of magnetic field in which the subsidiary instability can occur extends through the main resonance. The coincidence of the subsidiary and main resonances is a condition particularly favorable to *low-level* limiting because at resonance maximum energy transfer occurs between the input signal and the spin-magnetization vector. This is shown by a calculation of the critical RF magnetic field (h_{crit}) at which nonlinearity sets in:[3]

$$h_{\text{crit}} = \frac{\Delta H \Delta H_k}{4\pi M_s} g(\theta). \tag{1}$$

where

ΔH = line width of uniform precessional resonance,
ΔH_k = line width of spin wave having wave-number k,
$4\pi M_s$ = saturation magnetization,
θ = angle between H_z and the direction of propagation of the half-frequency spin waves.

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[1] R. W. Damon, "Relaxation effects in ferrimagnetic resonance," *Rev. Modern Phys.*, vol. 25, pp. 239–245; January, 1953.

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[3] H. Suhl, "Nonlinear behavior of ferrites at high microwave signal levels," PROC. IRE, vol. 44, pp. 1270–1284; October, 1956.

[4] H. Suhl, "Theory of ferromagnetic resonance at high signal powers," *J. Phys. Chem. Solids*, vol. 1, pp. 209–227; January, 1957.

[5] R. F. Soohoo, "Power limiting using ferrites," 1958 IRE NATIONAL CONVENTION RECORD, pt. 1, pp. 36–47.

[6] G. S. Uebele, "Characteristics of ferrite microwave limiters," IRE TRANS. ON MICROWAVE THEORY AND TECHNIQUES, vol. MTT-7, pp. 18–23; January, 1959.

For regions of limiting described in this paper, the function $g(\theta)$ approaches unity,[3] which is its minimum value.

Single-crystal yttrium-iron-garnet (YIG) is particularly suited to low-level limiting, since it has a very narrow resonance line width, a narrow ΔH_k, and a saturation magnetization of about 1800 gauss.

LeCraw, Spencer, and Porter[7] have demonstrated that for a single-crystal YIG sphere, the line width improves directly with the surface polish. LeCraw and his co-workers obtained resonance line widths as low as 0.52 oersted at 9200 Mc by polishing the sphere to a surface finish of better than 0.1 μ.

Experimental verification of (1) for the limiting threshold under coincidence of the main and subsidiary absorption peaks was also obtained.[8] This coincidence occurs when

$$2N_t 4\pi M_s \geq \frac{f}{\gamma} \geq N_t 4\pi M_s, \qquad (2)$$

where

f = signal frequency in Mc,
γ = 2.8 Mc per oersted
(The definition for γ used here differs by 2π from the γ used in the References, where it is defined in terms of the angular frequency.)
N_t = transverse demagnetizing factors for spheroid $(= N_x = N_y)$.

For a YIG sphere ($N_t = N_z = \frac{1}{3}$), having $4\pi M_s = 1800$ gauss, (2) yields lower- and upper-frequency limits of 1680 to 3360 Mc, respectively. Spencer, *et al.*,[8] observed nonlinear effects in the frequency range from 1600 to 3200 Mc with a limiting level at 2200 Mc in reasonable agreement with (1). These measurements were recently extended by Rossel.[9]

A general plot of (2) for various spheroidal geometries is shown in Fig. 1. For example, for low-level limiting (coincidence of subsidiary and main resonance) at *L* band, a YIG disk with $N_z = 0.670$ and $N_t = 0.154$ will have optimum operation near 1200 Mc, and a theoretical operating range from 860 to 1720 Mc.

The practical use of single-crystal YIG as a low-level and low-loss passive limiter was first demonstrated by DeGrasse.[10] He used two crossed-strip-transmission-line half-wave resonators oriented at right angles to one another to obtain maximum decoupling between resonators. We have based some of our work on this same circuit arrangement.

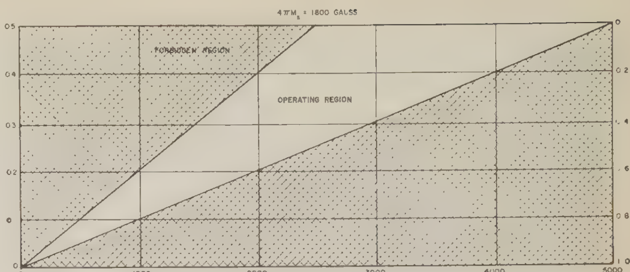

Fig. 1—Frequency region for low-level limiting as a function of ferrite geometry for YIG.

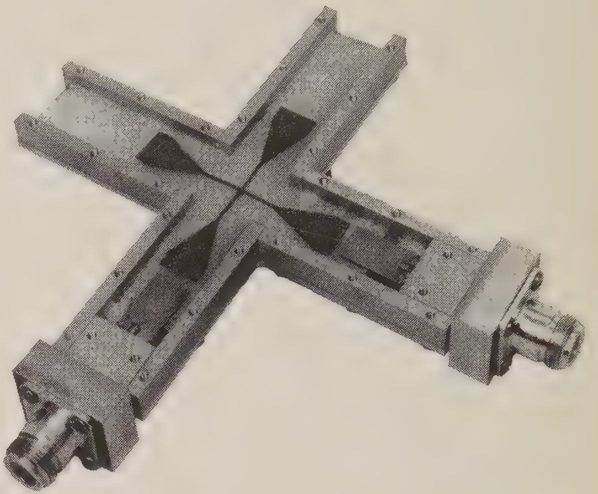

Fig. 2—*S*-band low-level limiter.

III. *S*-BAND LIMITER

An *S*-band limiter (with the top ground plane removed) is shown in Fig. 2. The strip-transmission-line resonators are open circuited at each end, so that there is an RF magnetic-field maximum at their centers, where the resonators cross. A 0.020-inch-diameter single-crystal YIG sphere is placed between the strips at their crossover point and biased to ferrimagnetic resonance (uniform precession of the spins). The resonators will then be coupled through the off-diagonal component of the susceptibility tensor. This process can be visualized in the following manner.

The driving RF magnetic field in the input resonator will fan out the spin magnetization vector. The vector will precess about the dc magnetization and in turn will induce an RF magnetic field in the output resonator. Thus, essentially all the RF energy is coupled through the YIG sphere, which can be considered a miniature microwave resonator with a very high unloaded *Q*. For a bandwidth ($\gamma \Delta H$) of 1 Mc, yields an unloaded *Q* of the order of 3000 at *S*-band. Such a miniature high *Q* resonator has many other potential applications in microwave circuits: electronically tunable preselector, filter, and panoramic receiver.

The single-crystal YIG resonator is coupled to and, therefore, loaded down by the strip-transmission-line resonators. This explains why the device has a 3-db bandwidth of approximately 70 Mc instead of a bandwidth of about 1 Mc. In fact, our theoretical investigation of the device has been based on an analysis of a three-resonator filter for minimum insertion loss.[11] This analysis shows that for minimum insertion loss, the input and output couplings should be tight, while the coupling to the center resonator (the YIG sphere) should be relatively loose. The resonators have been substantially reduced in width in the region where the YIG sphere is located in order to increase the RF magnetic field.

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[7] R. C. LeCraw, E. G. Spencer, and C. S. Porter, "Ferrimagnetic line width in yttrium iron garnet single crystals," *Phys. Rev.*, vol. 110, pp. 1311–1313; June, 1959.

[8] E. G. Spencer, R. C. LeCraw, and C. S. Porter, "Ferromagnetic resonance in yttrium iron garnet at low frequencies," *J. Appl. Phys.*, vol. 29, pp. 429–430; March, 1958.

[9] F. C. Rossel, "Subsidiary resonance in the coincidence region in yttrium iron garnet," *J. Appl. Phys.*. vol. 31, pp. 2273–2275; December, 1960.

[10] R. W. DeGrasse, "Low-loss gyromagnetic coupling through single-crystal garnets," *J. Appl. Phys.*, vol. 30, pp. 155–156; Suppl. April, 1959.

The transmission characteristic for the *S*-band limiter is shown in Fig. 3. The insertion loss is 0.6 db and the limiting threshold is −26 dbm (3 μw). The dynamic range is greater than 30 db. The power output actually drops several db from its threshold limiting value. (This characteristic can be changed to a slightly rising output-power slope, if desired, by changing the coupling coefficients.) The limiting threshold level, where the spin precession angle "sticks," is quite pronounced. This is seen more clearly when the YIG sphere is placed in a microwave transmission cavity and insertion loss is measured as a function of input power. The dissipative part of the magnetic susceptibility χ'' can be computed from this measurement. Fig. 4 is a plot of the decline in χ'' as a function of power level. The correlation of the measured values to the theoretical curve is very good.

The YIG sphere used for the above measurements had a line width $\Delta H = 0.37$ oersted measured at 5200 Mc. The dc magnetic field is adjusted to uniform precessional resonance, that is, a signal frequency of 2000 Mc would correspond to 715 gauss. Care must be taken in adjusting the magnetic field to ensure that it is not biased to one of a number of magnetostatic modes[12] in the YIG sphere that have higher insertion loss and, apparently, higher limiting threshold.

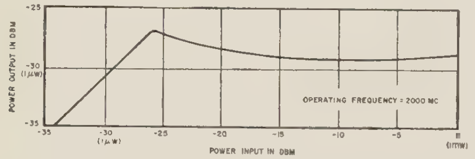

Fig. 3—Transmission characteristic of *S*-band limiter.

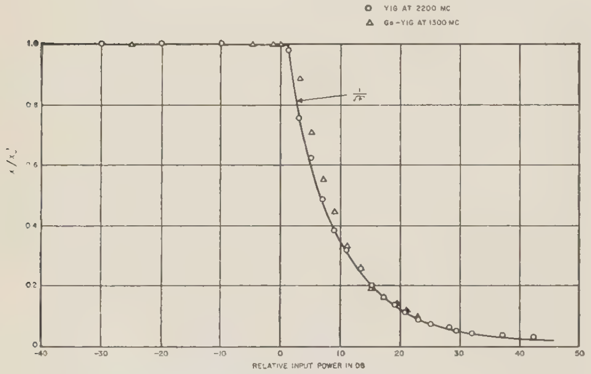

Fig. 4—Magnetic susceptibility of YIG and Ga-YIG spheres as a function of input-power level.

Although the limiting characteristic (Fig. 3) was measured at 2000 Mc, we have obtained similar performance at frequencies between 1850 and 3400 Mc by substituting other resonators and readjusting the coupling parameters and the magnetic field.

IV. L-Band Limiter

As Fig. 1 indicates, for low-level limiting at 1200 Mc using pure YIG, an oblate ellipsoid of revolution is required, having $N_z = 0.670$ and $N_t = 0.165$. However, to fabricate such an ellipsoid with a diameter of about 0.030 inch with an optical finish is difficult. A disk was therefore chosen to approximate the ellipsoid.

To achieve the lowest line width possible, YIG disks were X-ray oriented, cut with the hard axis [100] perpendicular to the plane of the disk, and then polished.

Line width and decline of magnetic susceptibility as a function of frequency and power level were measured for three disks of various thickness-to-diameter ratios. These measurements showed that the line width increases rapidly as the frequency is decreased, being 40 oersteds at 1200 Mc. The increase is caused by the YIG disks not being completely saturated at these low frequencies, as well as edge effects.[13] Limiting at low power levels was not obtained.

Another approach is the use of a sphere (easy to polish) having a reduced saturation magnetization, whose value can be determined from (2). Thus, using a narrow line-width material with a saturation magnetization of 1000 gauss, a limiter with a theoretical operating range from 950 to 1900 Mc can be constructed.

Experiments had been reported on decreasing the saturation magnetization of YIG by gallium substitution.[14] The line width remained narrow, increasing linearly with decreasing saturation magnetization in a 1:1 ratio.

Single crystals of Ga-YIG, having a saturation magnetization of 980 gauss and a Curie temperature of 206°C, were obtained from Microwave Chemicals Laboratory. Several spheres of this material were ground and polished to a Linde A finish. Measurements of the polished spheres indicated a very narrow line width (0.72 oersted measured at 5200 Mc), and low-level limiting was successfully obtained.

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[11] J. Taub and B. Bogner, "Design of three-resonator dissipative band-pass filters having minimum insertion loss," Proc. IRE, vol. 45, pp. 681–687; May, 1957.

[12] R. L. Walker, "Magnetostatic modes in ferromagnetic resonance," *Phys. Rev.*, vol. 105, pp. 390–399; January, 1957.

[13] R. C. LeCraw, private communication.

[14] E. G. Spencer and R. C. LeCraw, "Line width narrowing in gallium substituted yttrium iron garnet," *Bull. Am. Phys. Soc.*, Ser. II, vol. 5, p. 58; January 27, 1960.

A plot of the magnetic susceptibility as a function of power level that has the same sharp break as pure YIG is shown in Fig. 4. The decline has the $P^{-1/2}$ dependence predicted by Suhl.

An *L*-band limiter with an adjustable permanent magnet is shown in Fig. 5. The measured value for the limiting-threshold power level was −21 dbm (8 μw), which was lower than expected. The operating band over which limiting was measured extended from 1000 to 1500 Mc. The results in an *L*-band crossed-resonator limiter are shown in Fig. 6. An insertion loss of 1.1 db was obtained at the center frequency (1305 Mc). The 0.2-db and 3-db bandwidths for fixed magnetic field are 8 and 43 Mc, respectively; SWR is 1.06 at center frequency.

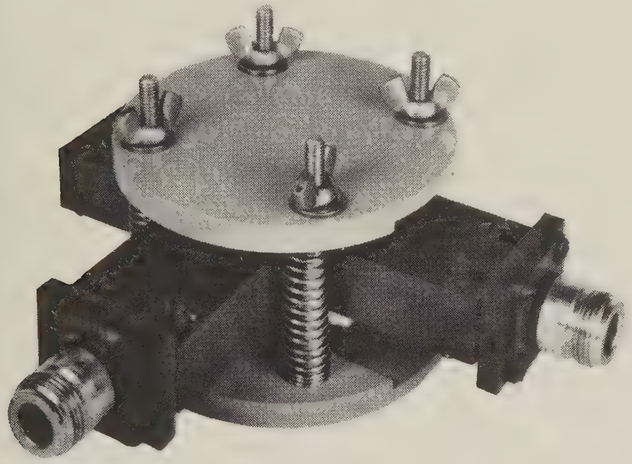

Fig. 5—*L*-band limiter (shown with adjustable permanent magnet).

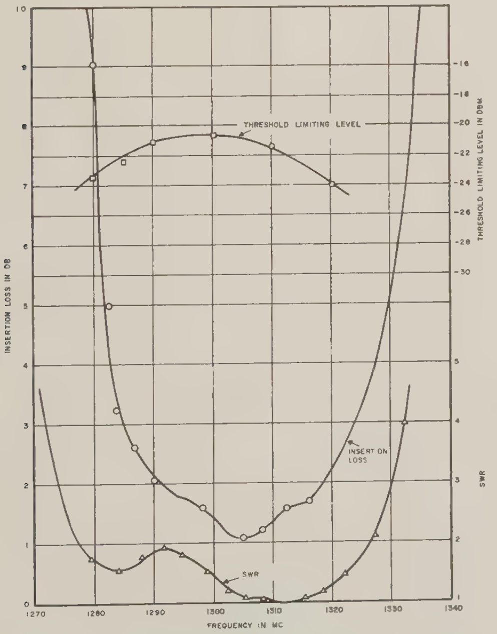

Fig. 6—Operating characteristics of *L*-band limiter

The output-power vs input-power characteristic is shown in Fig. 7, and indicates a dynamic range greater than 25 db. The SWR is also plotted as a function of the input-power level. The reflected portion of the incident power increases sharply as the input power is raised. The remainder of the input power is dissipated in the spin waves within the garnet.

Above limiting threshold, instabilities within the ferrite give rise to oscillations believed to be in the kilocycle region. In response to fast-rising pulses, the limiter exhibits a leading-edge spike about 0.1 μsec long, caused by the finite build-up time of the spin waves that result in limiting action.

A simple method of tuning the limiter was investigated, that is, capacitively loading the ends of the half-wave resonators with shorting plungers and by optimizing the magnetic field. Measurements showed a linear increase in limiting threshold and insertion loss with decreasing frequency (Fig. 8); a tuning range of 190 Mc was obtained. It is possible to devise other tuning methods in which the insertion loss is essentially independent of frequency.

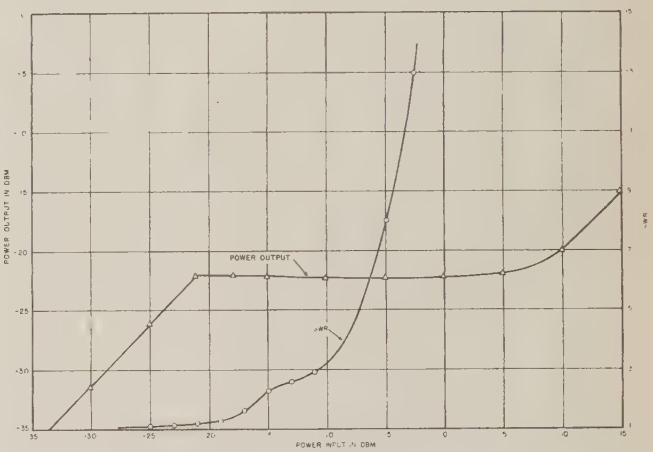

Fig. 7—Transmission characteristics of *L*-band limiter.

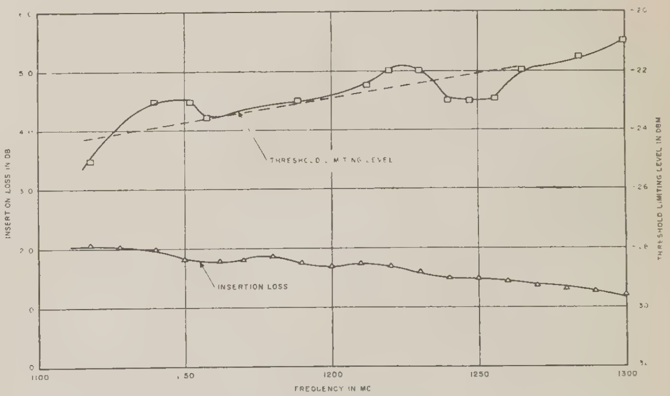

Fig. 8—Tuning characteristics of *L*-band limiter.

V. ELECTRONICALLY TUNABLE LIMITER-PRESELECTOR

Another interesting type of limiter has been operated in which the resonators were replaced by nonresonant transmission lines terminated in open circuits a quarter-wave from the YIG crystal. Thus, the principal frequency-determining parameter is the magnetic resonant frequency of the sphere, and is determined by the applied magnetic field.

By varying the magnetic field, an electronically tunable limiter-preselector was obtained. The test results (using an inferior sphere) were:

Frequency tuning range	2000 to 3400 Mc
3-db bandwidth	20 Mc
Threshold limiting level	−20 to −25 dbm
Insertion loss	4.4 db

Insertion loss can be reduced by sacrificing threshold limiting level.

VI. OTHER LIMITING CONFIGURATIONS

In the limiters described, the κ' component of the off-diagonal element of the ferrite susceptibility tensor[15] is used to couple two normally-decoupled orthogonal resonators. However, all of the χ and κ elements in the susceptibility tensor are dependent on the RF power level and can be used for the design of other limiters. Two methods for obtaining limiting that use other elements of the susceptibility tensor in appropriate microwave structures are the cavity limiter and the comb limiter.

A. *Cavity Limiter*

A cavity limiter has been operated that uses the selectivity of a high-Q single-tuned resonator and the χ' component of the diagonal element of the susceptibility tensor. The operation of this limiter is as follows.

A quarter-wave resonator is (Fig. 9) tuned to a frequency f_0. A ferrite sample is placed on the center conductor near the shorted end of the resonator where the RF magnetic field is maximum. The dc magnetic field is oriented at right angles to the RF magnetic field and adjusted to a field strength slightly less, or greater, than that required for uniform precession at cavity frequency f_0. A reactive component will be introduced into the cavity circuit by the ferrite that will retune the cavity to a new resonant frequency f_1. The cavity, with RF power levels below P_{crit}, will pass a band of frequencies centered about f_1 with a minimum of insertion loss. However, when the RF signal is increased above the critical threshold, the decline in the reactive component χ' will detune the cavity and thereby increase its insertion loss at frequency f_1.

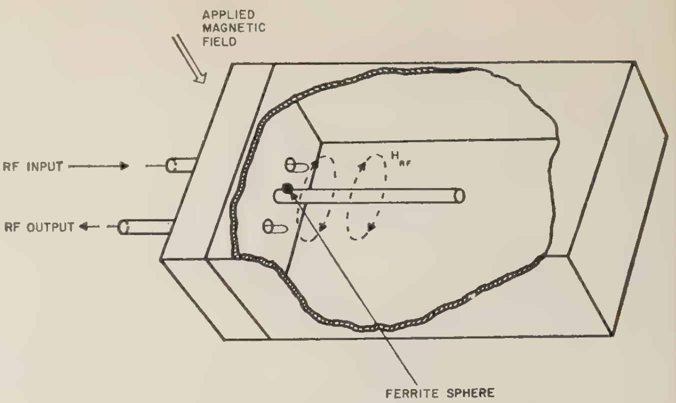

Fig. 9—Slab-line single-tuned cavity power limiter.

An experimental cavity limiter using this technique was constructed in slab-line (Fig. 9). This limiter incorporates a single-crystal YIG sphere with a resonance line width of about 1 oersted. The limiting characteristic is a plateau similar to that in Fig. 6. The measured characteristics are:

Center frequency	2590 Mc
Threshold limiting level	−20 dbm
Insertion loss (low-level)	2 db
Dynamic range	20 db

The insertion loss of the limiter can be minimized by using high-Q microwave circuits, and operating the ferrite at a compromise dc magnetic field. In this way the magnetic losses are small but the reactive component is high enough to sufficiently detune the cavity from its unperturbed resonance.

The power level at which limiting occurs (once a ferrite material has been selected) can be varied by moving the ferrite axially along the center conductor to regions of lower or higher RF magnetic-field strength.

B. *Comb Limiter*

A limiter has been operated that uses the inherent decoupling between two adjacent quarter-wave TEM-mode resonators. The garnet spin system is then used as an RF power-level-dependent coupling element between the two resonators (Fig. 10). This configuration has the advantages of compactness and ease in cascading. Furthermore, it is of special interest when used in conjunction with a traveling-wave maser amplifier, where the comb-type slow-wave structure has found wide application.[16,17]

The measured characteristics of a comb limiter are:

Center frequency	2638 Mc
Threshold limiting level	−15 dbm
Dynamic range	25 db
Insertion loss	10 db

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[15] The susceptibility tensor is given by

$$\begin{bmatrix} \chi & -j\kappa & 0 \\ j\kappa & \chi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

where $\chi=\chi'-j\chi''$ and $\kappa=\kappa'-j\kappa''$.

[16] R. W. DeGrasse, E. O. Schulz-DuBois, and H. E. D. Scovil, "Three level solid-state traveling wave maser," *Bell Sys. Tech. J.*, vol. 38, pp. 305–334; March, 1959.

[17] S. Okwit, F. Arams, and J. G. Smith, "Electronically tunable traveling-wave masers at *L* and *S* Bands," PROC. IRE, vol. 48, pp. 2025–2026; December, 1960.

The comb limiter that was fabricated is an experimental model for testing feasibility, and it is believed that better performance can be obtained. The comb limiter uses the dissipative part of the diagonal or off-diagonal elements of the susceptibility tensor, or a combination of these elements depending upon the positioning of the garnet sphere in plane A with respect to the comb fingers (Fig. 10). The garnet sphere used for this experiment was the same sphere used for the cavity limiter.

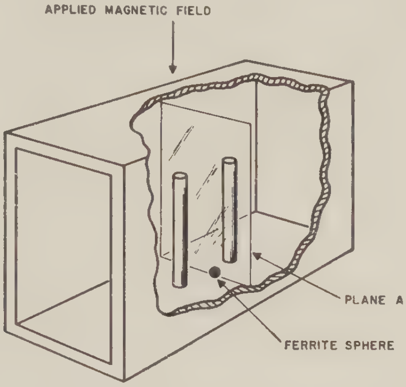

Fig. 10—Comb limiter (coupling not shown).

VII. Conclusions

The use of a polished single-crystal YIG of narrow line width in *S*-band and *L*-band low-level-limiter preselectors has been investigated.

The *S*-band limiter uses unsubstituted YIG and has an insertion loss of 0.6 db, a limiting threshold of -26 dbm, and a dynamic range greater than 30 db.

The *L*-band limiter uses specially grown gallium-substituted YIG crystals. When ground into spheres and polished to a high finish, these crystals exhibit extremely narrow line widths. The *L*-band limiter has an insertion loss of 1.1 db, a limiting threshold of -21 dbm, a dynamic range greater than 25 db, and a tuning range from 1120 to 1305 Mc. Detailed data on frequency sensitivity and SWR indicates that such limiters have high off-band rejection and fair power-handling capability. A leading-edge spike of about 0.1 μsec duration was observed.

The decline of the various components of the magnetic-susceptibility tensor can be used to construct other types of limiters. The operation of three of these —the electronically-tunable preselector, the cavity limiter, and the comb limiter—has been described and data on experimental models given.

Correspondence

The Silicon Cryosar*

For four years members[1] of our laboratory have been studying electrical characteristics of silicon-alloyed *p-n* junction diodes at a very wide range of temperatures, *i.e.*, from 1.9°K to 600°K. During this research on the silicon diode, negative-resistance characteristics have been found in the forward direction of the diodes at 4.2°K. As the result of this research, the silicon cryosar has been developed independently of the study of the germanium cryosar reported by McWhorter and Rediker.[2] The main difference between these two cryosars is that, in the germanium cryosar, negative resistance is observed only when the germanium crystal has compensated impurities; on the other hand, the silicon cryosar shows negative-resistance characteristics with uncompensated impurity silicon crystals.

The silicon cryosar is constructed from one silicon wafer whose thickness ranges from 0.05 mm to 0.3 mm, and from two contacts, which are ohmic at room temperature, attached to both surfaces of this wafer. The resistivity of the silicon wafers investigated ranged from 0.1 to 1000 Ω-cm at room temperature. To form the ohmic contacts, antimony-doped gold is alloyed for *n*-type silicon and aluminum plate, or gallium-doped gold is alloyed for *p*-type.

At room temperature, the silicon cryosar has good conductivity for both directions of current flow; however, at a temperature lower than 10°K, its conductivity becomes quite low at small applied voltages. Fig. 1 shows the dc-voltage-current characteristics of the silicon cryosar at 4.2°K.

As shown in this figure, the dc-voltage-current characteristics of the silicon cryosar at 4.2°K are divided into four regions. In the first region, the silicon cryosar shows high ohmic resistivity up to the breakdown voltage. In the next region, the current increases very rapidly during a small increase in the voltage. In the third region, remarkable negative-resistance characteristics are shown; namely, the voltage decreases to a small value. In the final region, the cryosar again shows low positive-resistance characteristics.

With regard to dynamic characteristics of the silicon cryosar, negative resistance has been observed by the following methods. First, when rectangular voltage was applied to the silicon cryosar through a high resistor, relaxation oscillations were observed. Second, when high-frequency sinusoidal voltage was applied to the silicon cryosar through a moderate-value resistor, it was observed by the voltage-time curve that the terminal voltage of the silicon cryosar decreased suddenly in each half cycle of the voltage.

Fig. 2 shows the waveforms of the relaxation oscillation. In this figure the applied-voltage form is shown in the upper curve. The center curve shows the terminal voltage of the silicon cryosar, and the lower curve is the current waveform of the circuit.

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* Received by the IRE, May 8, 1961.

[1] H. Izumi, "The Temperature Dependence of the Electrical Characteristics of the Silicon Alloyed Junction," *Repts. Elec. Commun. Lab., N.T.T.*, vol. 7, pp. 123–132; April, 1959.
H. Izumi, "The Electrical Characteristics of the Silicon Alloyed Junctions at Very Low Temperature," *Repts. Elec. Commun. Lab., N.T.T.*, vol. 7, pp. 339–344; September, 1959.

[2] A. L. McWhorter and R. H. Rediker, "The cryosar—a new low-temperature computer components," Proc. IRE, vol. 47, pp. 1207–1213; July, 1959.

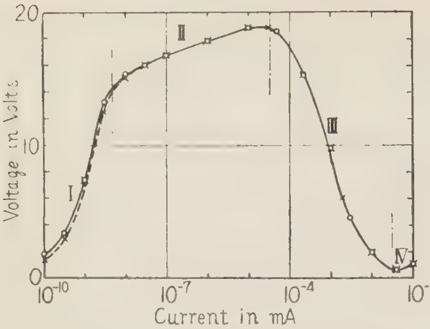

Fig. 1—The dc-voltage-current characteristics of the silicon cryosar. I is the high-impedance region, II is the current-increasing region, III is the negative-resistance region, and IV is low-impedance positive-resistance region. ○ is the normal direction, and × is the reverse direction of current flow.

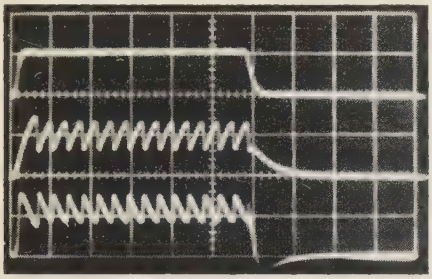

Fig. 2—Three traces illustrate the voltage-time curve of the relaxation oscillation. The time scale of the figure is 1 μsec per large division. The vertical scale for the upper trace (the applied voltage) is 20 volts per large division; for the center trace (the terminal voltage), 10 volts per large division and, for the lower trace (the current through the circuit), 10 volts, *i.e.*, 2 ma per large division.

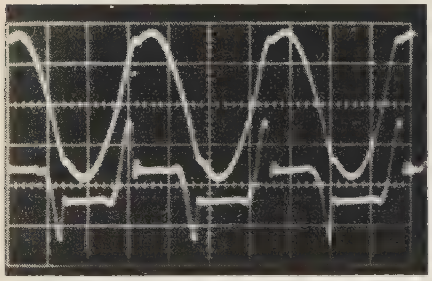

Fig. 3—Two curves indicate the voltage-time curve of the switching action of the silicon cryosar. The vertical scale for the upper curve (the applied waveform) is 100 volts per large division and for the lower curve (the terminal voltage of the cryosar), 50 volts per large division. The time scale is 1 μ sec per large division.

The repetition frequency of this oscillation is determined mainly from the charging speed of the capacitance of the silicon cryosar (about 100 $\mu\mu$f) through a series resistor. The discharging speed through the negative resistance of the silicon cryosar is less than 0.1 μsec.

When the high-frequency sine wave (about 300 kc) is applied through a resistor to the silicon cryosar from the low-impedance source, the terminal voltage of the cryosar initially increases sinusoidally. However, at the breakdown voltage it falls suddenly to some low value due to negative resistance. This shows that the cryosar switches from the OFF to the ON state.

Fig. 3 shows these voltage changes vs time. The waveform of the terminal voltage of the silicon cryosar is shown in the lower curve of the figure, and the upper curve shows the applied voltage. As can be understood from this figure, the silicon cryosar switches bilaterally because two alloyed electrodes are the same, and the device is symmetrical with respect to both directions of current flow. The switching time is about 50 mμsec, and a maximum-minimum ratio of a voltage as high as 7 is obtained in the optimum case. Higher switching speed can be expected by reducing the inductance of the circuit.

The author wishes to thank N. Inoue and K. Matano for measuring the electrical characteristics and A. Kobayashi for helpful discussion of these phenomena.

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Noise Figure and Stability of Negative Conductance Amplifiers*

Van der Ziel[1] has considered the overall noise figure of a negative conductance preamplifier connected through an ideal transformer to a conventional receiver assuming that the output conductance of the preamplifier, g_s-g_d, (Van der Ziel's notation is used) is positive. He considers two cases: a) The turns ratio n is one. He assumes the "high gain" condition $g_s \cong g_d$ and shows that an overall excess noise figure g_x/g_d may be attained. b) The turns ratio is controllable. Here he assumes that the preamplifier output conductance $n^2(g_s-g_d)$ is of such value as to minimize the *receiver* noise figure and shows g_x/g_d may again be attained.

It is the purpose of this note to consider the same problem from a different point of view, namely, to drop the requirement $g_s > g_d$ and to optimize g_s in a way to be described below. This procedure leads naturally to a consideration of stability, and suggests a quantitative definition of stability which can then be introduced into the equations. The results are: 1) For a given stability, neither the high gain assumption nor the assumption in case b) is optimum, and the optimum g_s may be greater than or less than g_d. 2) Low noise figure and high stability cannot be simultaneously attained. In particular, the lowest possible overall excess noise figure g_x/g_d, (which is also the noise measure and optimum noise measure of the preamplifier[2]) is attained with the preamplifier exactly at the verge of oscillation.

If the exchangeable gain[3] of the preamplifier and the receiver are denoted by $A_{\mathrm{E}1}$ and $A_{\mathrm{E}2}$ and the exchangeable noise figures[3] by $F_{\mathrm{E}1}$ and $F_{\mathrm{E}2}$, the overall noise figure may be written $F=F_{\mathrm{E}1}+(F_{\mathrm{E}2}-1)/A_{\mathrm{E}1}$, where $F_{\mathrm{E}1}=1+g_x/g_s$, $F_{\mathrm{E}2}=1+A+R_{n0}(g_s-g_d)/N+g_{n\infty}N/(g_s-g_d)$, $A_{\mathrm{E}1}=g_s/(g_s-g_d)$, and $N=1/n^2$. Combining them, we get a general equation for F:

$$F-1=(1/g_s)[g_x+A(g_s-g_d)+g_{n\infty}N + R_{n0}(g_s-g_d)^2/N]. \quad (1)$$

The independent variables are N and g_s and there are no restrictions on g_s. At this point it is convenient to define a stability factor, S, as follows: $S=g_l/g_d+g_s/g_d-1$, where g_l is the load conductance seen by the preamplifier. If S is equal to or less than zero, the preamplifier is unstable and the more positive S is, the farther is the system from instability. Since $g_l=Ng_i$ where g_i is the input conductance of the receiver we have

$$S=Ng_i/g_d+g_s/g_d-1, \quad (2)$$

and thus, for given g_s, the larger N, the greater the stability. The minimum value of the noise figure, regardless of stability, is of fundamental interest. This is determined by minimizing (1) with respect to both g_s and N by the conventional method, and the result is that for $N=0$ and $g_d=g_s$ (high gain)

$$(F-1)_{N,g_s}=g_x/g_d, \quad (3)$$

which is in agreement with the conclusion of Van der Ziel and the more general conclusion of Penfield.[2] It should be noted that this lowest possible noise figure is obtained at the expense of stability, for [see (2)] S is equal to zero. Thus, if g_d should become larger by an infinitesimal amount, or if either g_s or g_l should become smaller by an infinitesimal amount, the system would oscillate. In practice then, this lowest possible noise figure is not attainable. Furthermore, the question of the sign of g_s-g_d has not really been touched upon in this degenerate case. What is required is an expression for noise figure as a function of S rather than N, in which g_s has been optimized. (The corresponding value of g_s will be designated as $(g_s)_{\mathrm{opt}}$).

In principle, this could be done by solving (2) for N and substituting this value into (1) followed by minimization with respect to g_s. The resulting expressions are rather unwieldy. Useful equations are obtained as follows. The optimum value of g_s for arbitrary N is obtained from (1).

$$(g_s)_{\mathrm{opt}}^2 = g_d^2+g_dN(t-A)/R_{n0}+g_{n\infty}N^2/R_{n0}, \quad (4)$$

where $t=g_x/g_d$. This is inserted in (1) and (2) giving

$$(F-1)_{g_s}=2[g_dR_{n_0}(t-A)/N+R_{n0}g_{n\infty} + R_{n0}^2g_d^2/N^2]^{1/2}+A-2g_dR_{n0}/N, \quad (5)$$

$$S+1=Ng_i/g_d+(g_s)_{\mathrm{opt}}/g_d. \quad (6)$$

Since low noise figure is associated with small values of N, it is useful to write (4)–(6) in the limit of small N.

$$(g_s)_{\mathrm{opt}}=g_d+Ng'/2, \quad (7)$$

$$(F-1)_{g_s}=t+(N/g_d)[g_{n\infty}-(g')^2R_{n0}/4], \quad (8)$$

$$S=N(g_i+g'/2)/g_d, \quad (9)$$

---

* Received by the IRE, June 6, 1961.

[1] A. Van der Ziel, "Note on the noise figure of negative conductance amplifier," Proc. IRE, (*Correspondence*) vol. 48, p. 796; April, 1960.

[2] P. Penfield, Jr., "Noise in negative-resistance amplifiers," IRE Trans. on Circuit Theory, vol. CT-7, pp. 166–170; June, 1960.

[3] H. A. Haus and R. B. Adler, "An extension of the noise figure definition," Proc. IRE, vol. 45, pp. 690–691; May, 1957.

where $g' = (t - A)/R_{n0}$. Eq. (9) can be substituted into (7) and (8):

$$(g_s)_{\text{opt}} = g_d + S g_d g'/2(g_i + g'/2), \quad (10)$$

$$(F-1)_{g_s} = t + S(g_{n\infty} - (g')^2 R_{n0}/4)/(g_i + g'/2). \quad (11)$$

The quantities g', $g_i + g'/2$ and $g_{n\infty} - (g')^2 R_{n0}/4$ are important. It can be shown that if t is less than the optimum excess noise figure of the receiver (and this is the only case of interest) the last quantity above is positive. g' may be positive or negative since A may be either positive or negative and R_{n0} is always positive. $g_i - g'/2$ must be positive in this first order expansion. This is not a severe restriction and if necessary can be removed by carrying out a higher order expansion.

Eq. (5) may be easily evaluated for large S, *i.e.*, large n, and the resultant noise figure is $1 + A + 2(R_{n0} g_{n\infty})^{1/2}$ which is just the noise figure of the receiver. Thus, as the stability varies from zero to infinity the overall noise figure varies from $1 + t$ to the noise figure of the receiver.

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Tunnel-Diode One-Shot and Triggered Oscillator*

A note by Kaenel[1] describes an extremely simple and useful one-tunnel-diode flip-flop. This circuit requires a bidirectional pulse which may not be available. A purpose of this note is to point out that an identical circuit with modified bias will produce the required pulse.

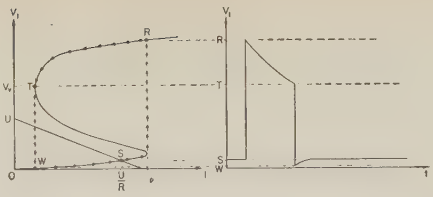

Fig. 1—Low-voltage bias condition.

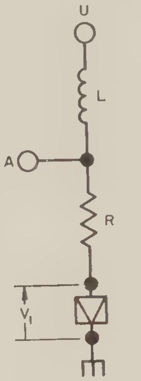

Fig. 2—Tunnel-diode one shot.

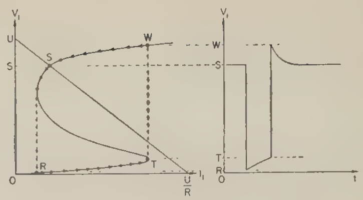

Fig. 3—High-voltage bias condition.

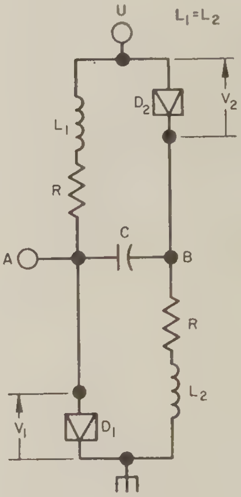

Fig. 4—Triggered oscillator.

With the use of a supply voltage slightly higher or lower than that used for a bistable operation, the circuit becomes monostable. If a bias condition is selected such that the resistive load line intersects the characteristic tunnel-diode curve at a voltage below that for peak current, as shown in Fig. 1, and a positive spike is applied at point A, shown in Fig. 2, the circuit delivers a positive pulse followed by a negative overshoot, as shown in Fig. 1. By selecting a higher bias voltage (and using a negative trigger spike), the circuit delivers a similar but inverted pulse, as shown in Fig. 3. This negative pulse has a larger overshoot and is, therefore, preferable as a driver for the flip-flop described by Kaenel.[1]

The switching action of the circuit will not be discussed, as the switching of tunnel diodes has been described before, and the locus of the operating point of the diode is shown by the arrowed lines in Figs. 1 and 3, point S being the stable operating point.

When two of these circuits are capacitively coupled, an oscillator is obtained; however, this oscillator requires an initiating pulse. The typical oscillator circuit is shown in Fig. 4. This oscillator has two stable states. One is a stable dc state, and the other is a stable ac state where the circuit is in a stable oscillation.

As in the above discussion of the one shot, this circuit can be biased in a low-voltage or high-voltage state. Fig. 1 shows the low-voltage biasing condition. We see that both diodes then have a stable point at S. When both diodes are in this stable condition, the oscillator is in its dc state. If a positive trigger pulse is applied at point A, the voltage V_1 will be as shown in Fig. 1 for the case of the one shot. The sudden jump of V_1 from T down to W is transmitted to point B by the capacitor C. This causes V_2, the voltage across diode D_2, to rise suddenly, and the same one-shot action takes place in the right-hand side of the circuit. As V_2 jumps downward from T to W, it triggers the left side through capacitor C. Therefore, the one-shot action takes place alternately on each side, and a stable oscillatory state exists (ac state).

The triggered oscillator can be returned to its dc state from its ac state by grounding point A for a time not less than one period of the oscillator. An additional condition is now imposed on the biasing of the diode which is that $I_p > U/R$ (see Fig. 1). If this limitation does not exist, it is possible for the current through L_1 to be greater than I_p when point A is removed from ground, in which case the oscillator will continue in its ac state. After point A is ungrounded, the operating point of D_1 moves to point S, and the oscillator is back in its dc state, as D_2 returned to point S during the period A was grounded.

The high-voltage case is identical in principle to the low-voltage case, except that the oscillator can now be turned off by placing point A at a potential greater than S (see Fig. 3) for at least one period of the oscillator.

One possible application of the triggered oscillator is as a memory unit, as it has two stable states and produces an ac signal for nondestructive readout.

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* Received by the IRE, June 7, 1961.

[1] R. A. Kaenel, "One-tunnel-diode flip-flop," Proc. IRE (Correspondence), vol. 49, p. 622, March, 1961.

A Tunnel-Diode Slot Transmission Amplifier*

A negative conductance waveguide transmission type amplifier has been built and operated at 2.7 kMc. The amplifier consists of a tunnel diode mounted within an S-band waveguide endplate slot. In operation the slot assembly behaves as a guide-to-guide coupler with reflection and transmission coefficients greater than unity. It is believed that this is the first description of a tunnel-diode microwave amplifier in which a resonated slot or linear electromagnetic radiator provides coupling to the source and load conductances as well as the distributed capacitance and inductance necessary to maintain resonance.

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* Received by the IRE, June 2, 1961. This work was supported in part by AF Cambridge Res. Ctr. under Contract No. AF 19(604)3508 at Hughes Aircraft Co., Culver City, Calif.

The construction details of the device are shown in Fig. 1. The endplate containing the slot is fabricated in two pieces which are separated by a 0.025 inch mylar insulator. This construction provides microwave continuity between the tunnel diode and the slot while simultaneously permitting an appropriate dc potential to be maintained across the diode. In order to prevent oscillations from occurring in the biasing circuit, a small resistor (not shown in the figure) is connected between the insulated plates near their common perimeter. When the device was used as an endplate guide to guide coupler, it was necessary to place an additional mylar sheet between the split face of the endplate and one waveguide flange in order to prevent the biasing circuit from being shorted.

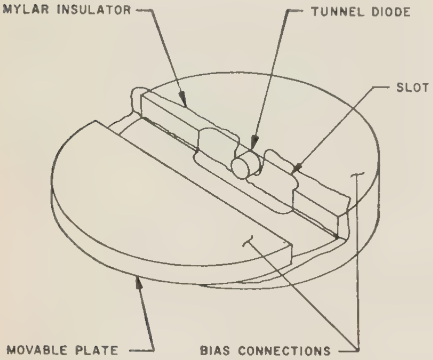

Fig. 1—Tunnel-diode slot amplifier.

In the transmission experiment a tuneable passive endplate slot was inserted into a waveguide system which had been provided with adequate input and output isolation. The slot was then tuned to resonance and the transmitted power level was noted. After the passive endplate slot was removed it was observed that the transmitted power was essentially unchanged. The endplate slot containing the tunnel diode was then inserted into the waveguide system and the transmission gain was measured by introducing sufficient attenuation to produce the same transmitted power as before. Transmission gains of 8, 16 and 21 db have been obtained in the neighborhood of 2.7 kMc; a 3 db bandwidth of 21 Mc was observed for the amplifier which exhibited a center frequency gain of 16 db. The diodes used in the experiment were Hughes Aircraft Company's experimental point contact Gallium Arsenide tunnel diodes with peak currents in the neighborhood of 1 ma, capacitances less than 1 pf, and negative resistances of approximately 300 ohms.

The purpose of the experimental program was to determine the feasibility of obtaining amplification from the elements of a waveguide slotted antenna; consequently no noise figure measurements have yet been attempted. The endplate slot was selected for this experiment because of its geometrical simplicity and the fact that its properties are related in a known way to those of slots cut in the broad wall of a waveguide. The results obtained to date indicate that the development of a multiple element amplifying array is feasible.

During the course of the investigation it was observed that the diode slot configuration could be adjusted to the condition of oscillation. Under this condition the oscillator would lock onto a signal removed in frequency by several megacycles from the natural oscillation frequency. This lock on oscillator effect produced apparent signal gains in excess of 40 db over a 2 Mc bandwidth. The diode slot system acting as a combined microwave source and antenna element produced radiated power levels of 35 dbm. The power level attained was limited by the characteristics of the diode which was selected to match the radiation resistance of the slot.

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Neural Analogs*

The present vogue of indiscriminately equating "neural analogs" to biological neurons is as popular as it is erroneous. With a very few exceptions, most of the analogs proposed so far are vastly different from the biological original. The creators of these devices and systems rarely take the trouble to point out these differences, and, in some instances, they appear to be unaware of the essential properties of the neuron. In the recent papers by Hawkins[1] and by Brain[1] a number of misconceptions continued to be propagated.

First, a clarification on anatomy is in order. An abstracted schematic of a neuron is shown in Fig. 1. Axons, the output transmission lines of neurons, branch out into many fine fibers which terminate at synapses. They do not become dendrites, as stated by Hawkins. Dendrites are the converging branched cell inputs and are integral with the cell body.[2] The input signals to a cell are due to axons of other cells which either make synaptic connection with the dendrites of the given cell or which synapse directly onto the cell's body, as shown.

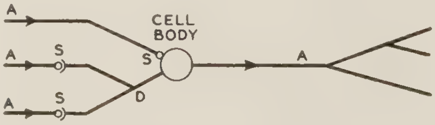

Fig. 1—Simplified representation of a neuron. A =axons. S =synapses, and D =dendrites.

Second, a correction must be made to Hawkins' statement of the function of a synapse. He states that a synapse transmits an attenuated impulse between one neuron and another. This is true only for a minute fraction of the synapses which have been investigated. The majority of synapses do not transmit electrical events at all. Rather, the axon spike (pulse) stops at the synapse where it triggers a chemical release mechanism. After diffusion across the synaptic boundary, the chemical (acetylcholine) initiates a new and different electrical event in the dendrite or at the cell body, depending on its location. The new electrical signal is not a spike; rather it is a long-lasting, low potential signal which then flows slowly and with attenuation.[3]

It is there, at the neuron's inputs, that the functions are continuous-variable, graded, and decremental in contrast to the discrete-variable, lossless axon signals. Thus the logics of a neuron begin to get very complex. These input properties are practically never included in analog descriptions. But it is precisely their intricate functions which play an important part in signal processing. A convincing summary of this complexity is given by Bullock.[4]

All of the so-called "adaptive" systems which have been constructed employ a "synapse" whose transmission varies with use. Although there is some neurophysiological evidence for variable synaptic transmission,[5] it is at best incomplete and controversial. There is no clear evidence that in intact tissue repeated transmission enhances the probability of future transmission. Also, it has been shown that a particular synapse may produce either excitatory or inhibitory effects at various times depending on the instantaneous signal environment in a cell.[6]

In his review, Hawkins points out that it sometimes has been taken into account that immediately after firing, the neuron's threshold briefly becomes infinite (absolute refractoriness). It should be pointed out that the exclusion of this parameter in a model is a most serious omission. Since it appears that the principal business of nerve-net functions involves time-varying interactions, such threshold changes must play an essential role. At least as important is another threshold change which is not mentioned at all. Immediately following the absolute refractory period is the so-called relative refractory phase, an essentially exponential decay toward resting threshold.[7] This decay has a time constant which is quite long compared to axon-spike durations

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* Received by the IRE, February 2, 1961.

[1] J. K. Hawkins, "Self-organizing systems—a review and commentary," Proc. IRE, vol. 49, pp. 31–48; January, 1961.
A. E. Brain, "The simulation of neural elements by electrical networks based on multi-aperture magnetic cores," Proc. IRE, vol. 49, pp. 49–52; January, 1961.

[2] F. Brink, Jr., "Excitation and conduction in the neuron," in "Handbook of Experimental Psychology," S. S. Stevens, Ed., John Wiley and Sons, Inc., New York, N. Y., pp. 50–93; 1951.

[3] J. C. Eccles, "The Physiology of Nerve Cells," The Johns Hopkins Press, Baltimore, Md., 270 pp.; 1957.

[4] T. H. Bullock, "Neuron doctrine and electrophysiology," *Science*, vol. 129, pp. 997–1002; April 17, 1959.

[5] J. C. Eccles and A. K. McIntyre, "The effects of disuse and of activity on mammalian spinal reflexes," *J. Physiol.*, vol. 121, pp. 492–516; September, 1953.

[6] S. W. Kuffler and C. Eyzaguirre, "Synaptic inhibition in an isolated nerve cell," *J. Gen. Physiol.*, vol. 39, pp. 155–184; September, 1955.

[7] I. Tasaki, "Nervous Transmission," Charles C Thomas, Springfield, Ill., 164 pp.; 1953.

and repetition rates; hence, it plays an important part in modifying signal processing in the neuron. An example of the significance of this parameter is described in an auditory model by Guttman, van Bergeijk, and David.[8]

Brain implies in his paper that he has devised a "comprehensive" simulation of neural elements. Since he includes even fewer parameters than those mentioned by Hawkins, the simulation is still more remote. Brain has it that the strength of an output signal depends on the previous history of the neuron. Such is certainly not the case in nature where with few exceptions the output is all-or-none, and to a first-order approximation has constant amplitude and duration.[9]

The biological nerve cell operates as an exceedingly complex element. The fact that it is a highly nonlinear device with a large number of time-varying parameters makes it very flexible. Neural modeling is tempting and interesting because abstracting even just a few properties permits a demonstration of a rich variety of behavior.

There has been a sharp increase in neural modeling activity during the last few years, and it is important to point out that two distinct philosophies are involved. One school seeks to make its "neurons" simulate biological function as closely as possible. The emphasis is on small scale and physiologically accurate modeling. Input-output relationships are made to be consistent with what is known of the biological parameters. The intent is to study closely the probable information-processing functions of neurons, and in so doing, to elucidate further the operations of the biological system.

In the second group of modelers (by far the most populous) the idea is to explore the "adaptive" and large-scale behavior of many quasi-neural elements randomly connected. Little care is taken to simulate neural properties accurately or fully. The intent seems to be titillation rather than elucidation. Since these abstractions are generally very imprecise, obviously incomplete, and frequently in error, little relevance to physiological nervous systems should be inferred. Above all, anthropomorphism is unwarranted.

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[8] N. Guttman, *et al.*, "Monaural temporal masking investigated by binaural masking," *J. Acous. Soc. Am.*, vol. 32, pp. 1329–1336; October, 1960.

[9] E. D. Adrian, "The Mechanism of Nervous Action. Electrical Studies of the Neurone," University of Pennsylvania Press, Philadelphia, Pa., 103 pp.; 1932.

Author's Comment[10]

We are indebted to Dr. Harmon for gallantly volunteering to unravel the fascinating complexity of the biological neuron system, and admire his dedication to its simulation down to the last detail. The single-minded tenacity and stoicism of the purist will always command respect, but I would draw a parallel between the present state of affairs in regard to "learning machines" (adaptive pattern-recognition systems which process numerous input signals simultaneously in a statistical manner) and the status of "flying machines" at the end of the nineteenth century. Is it not true that man's progress in the construction of *potentially useful* flying machines, as distinct from interesting scientific curiosities, is measured from the time he ceased to be obsessed with the flapping wings so vital to the birds he took for a model?

Surely the crux of the numerous differences of opinion so prevalent in the field of learning machines lies in basic motivation. The investigation of the detailed mechanism by which a man remembers, recognizes, and extracts generalities out of myriad simultaneous-data samples is assuredly a laudable enterprise, but is it any the less so to seek to construct a *useful* machine to perform in a similar manner? It does not follow that the machine must be an exact model in order to function satisfactorily The purist has no monopoly of virtue, and the unrepentant urchin who persists in draggling his worm where the water is muddiest frequently catches bigger fish than the "exact copy," dry-fly man.

The word "useful" has been stressed because it has a significant influence on the philosophical attitude being brought to bear on the problem. Reduced to its lowest terms, it is virtually synonymous with "a commercial proposition." It is perhaps unfortunate, but no matter how high their motivation, machine builders sooner or later must face the fact that unlimited funds are not available for the construction of large, expensive, scientific gimmicks. In the present instance, in considering machines which function by simultaneous statistical sampling, one soon finds oneself glibly postulating systems containing upwards of a thousand identical basic building blocks, plus peripheral equipment. With these boundary conditions, simplification to the highest degre possible is mandatory.

With regard to Dr. Harmon's objection to the use of the word "comprehensive," I would merely observe that the four primitive operations

1) addition of signals,
2) absolute inhibition of signals passing through one or more connections by signals in a controlling channel,
3) control on an all-or-none basis by a threshold level, and
4) a weighted connection which can have its value changed in the "learning" phase of operation,

have been made available in compatible components, and that these functions seem to be adequate to satisfy the majority of descriptive models. The circuits given were not intended to constitute an exhaustive list, but rather to be illustrative of the versatility of arrangements using carrier-operated multi-aperture magnetic cores. Thus, should a time-dependent threshold with exponential decay be desired, a gated carrier supplied to Fig. 11, with a little ingenuity, might very well satisfy the requirement. Fig. 6 is, of course, only part of the story; its output is taken along with similar connections to a threshold unit of the all-or-none kind.

As for the need for a weighted connection which can have its value permanently modified in the learning phase of operation, I have no doubt of its usefulness in enhancing the discrimination of pattern recognition machines. With regard to its relevance to human neural operation, I would ask whether anyone has succeeded in finding a plausible mechanism which does not make use of permanently modified connections to explain the retention of human memory through sleep and anesthesia, for 50 years.

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[10] Received by the IRE, March 20, 1961.

On Self-Organizing Systems*

The recent review by Hawkins[1] represents one possible approach to self-organizing systems that should prove useful. By regarding nervous systems as self-organizing it should be possible for physical scientists and biological scientists interested in this area to engage in a fruitful exchange of ideas. The Hawkins article, unfortunately, illustrates a danger in this approach. In undertaking to relate the nervous system to self-organizing systems an author must assume the responsibility of familiarizing himself with at least the elementary information available in both the physical and biological facets of the problem. Hawkins has failed to do so, at least with regard to biology.

Harmon points out some of the errors in the Hawkins paper; and there are numerous additional errors made by Hawkins. For example, it is stated that the arrival of about ten nearly simultaneous impulses will fire a neuron. In fact, the number of presynaptic spike impulses required to fire a neuron varies tremendously from one type of junction to another with a minimum of one[2] and an undetermined maximum. Related to this error is the statement that each neuron is connected to 10^2 to 10^3 other neurons. This property also is tremendously variable with a minimum near one[3] and a maximum that may be of the order of 10^3.[4] We are also told that "long neurons tend to transmit at a higher speed than short ones." One of the earliest established facts in electrophysiology, however, was that the activity

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* Received by the IRE, April 13, 1961.

[1] J. K. Hawkins, "Self-organizing systems—a review and commentary," Proc. IRE, vol. 49, pp. 31–48; January, 1961.

[2] T. H. Bullock, "Properties of a single synapse in the stellate ganglion of squid," *J. Neurophysiol.*, vol. 11, pp. 343–364; 1948. See especially, p. 348.

[3] A. A. Maximow and W. Bloom, "Textbook of Histology," W. B. Saunders Co., Philadelphia, Pa., pp. 188–190; 1952.

[4] D. A. Sholl, "The Organization of the Cerebral Cortex," John Wiley and Sons, Inc., New York, N. Y., pp. 57–58; 1956.

of neural processes of various diameters in a compound nerve could be distinguished by virtue of the fact that speed of conduction over the same distance varies by an order of magnitude.[5] Thus, conduction velocity varies with diameter, not length. Length may be correlated with diameter, but the correlation is low, and the primary relationship is between *diameter* and conduction velocity.

Other statements simplify matters to the point of being misleading. It is mentioned that "the alpha rhythm is sometimes regarded as a scanning mechanism." The evidence indicates that the alpha is probably the summation of fluctuations of certain of the analog voltages referred to by Harmon.[6] Although these local fluctuations will result in changes of threshold in the neurons involved, a network scanning mechanism becomes improbable. These same fluctuations in analog voltage have also been proposed as a possible basis for short-term memory as an alternative to the recirculation of signal sequences mentioned by Hawkins.[7] The distributed memory concept referred to is by no means established. The experiments mentioned in which "memory" is tested following cortical extirpations are difficult to interpret; the deficits in performance following these extirpations may be the result of losses in information handling capacity rather than any losses of storage capacity *per se.*

Harmon also criticizes the designers of adaptive systems for the incorporation of alterations of "synaptic" transmission in their models. His statement, "There is no clear evidence that in intact tissue repeated transmission enhances the probability of future transmission" is entirely unwarranted. Much of the evidence that repeated transmission does alter the probability of future transmission is cited in recent reviews[8,9] of the role of the central nervous system in learning. Although it has not been established with certainty that these alterations of probability of transmission take place at the synapse, evidence of synaptic changes as a result of use and disuse is mounting.[10,11]

Errors such as the ones mentioned above decrease the value of Hawkins' paper to physical scientists by conveying to them incorrect or outdated concepts. In the cases of the biological scientist, they plant a seed of doubt as to the accuracy of the remaining information contained in the paper.

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[5] T. C. Ruch and J. F. Fulton, "Medical physiology and biophysics," W. B. Saunders Co., Philadelphia, Pa., pp. 71–73; 1960.

[6] J. F. Field, Ed., "Neurophysiology," in "Handbook of Physiology," American Physiological Society, Washington, D. C., sect. 1, pp. 293–295; 1959.

[7] B. D. Burns, "The electrophysiological approach to the problem of learning," *Can. J. Biochem. and Physiol.*, vol. 34, pp. 380–388; 1956.

[8] V. E. Hall, Ed., "Annual Review of Physiology," Annual Reviews, Inc., Palo Alto, Calif., vol. 23, pp. 451–484; 1961.

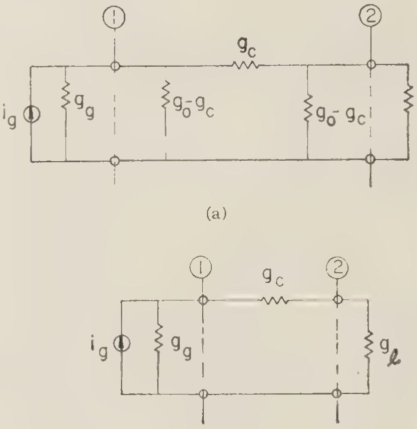
[9] Field, *op. cit.*, pp. 1471–1499; 1960.

[10] E. De Robertis, "Submicroscopic morphology and function of the synapse," *Exp. Cell Research*, suppl. 5, pp. 347–369; 1958.

[11] E. De Robertis, "Submicroscopic morphology of the synapse," *Internat. Rev. Cytol.*, vol. 8, pp. 61–96; 1959.

Stable Low-Noise Tunnel-Diode Frequency Converter*

A simple nonlinear resistance frequency converter can be represented by the equivalent circuit of Fig. 1(a)[1], provided all image and sum frequencies are short circuited, and the amplitude of the local oscillator voltage is much greater than the sum of the amplitudes of the voltages at the signal and intermediate frequency. In practical positive nonlinear resistances, the conversion conductance g_c must always be less than the average conductance g_0.[1] If, however, the incremental value of the nonlinear resistance is negative for some voltages, then g_c may equal or exceed g_0.[2]



(a)

(b)

Fig. 1—Equivalent circuit of simple nonlinear resistance mixers. Currents and voltages to the left of port 1 are at the signal frequency f_s, those to the right of port 2 are at the intermediate frequency f_i. ($f_s = f_i + f_{LO}$; f_{LO} = local oscillator frequency.) (a) $g_o = g_c$, (b) $g_o = g_c$. (i_g = generator current, g_g = generator conductance, g_o = average conductance of nonlinear resistance,[1] g_c = conversion conductance of nonlinear resistance,[1] g_L = load conductance.)

For the case $g_c = g_0$, the equivalent circuit of the converter reduces to Fig. 1(b). The conversion gain G_c (*i.e.*, the ratio of the IF output power to the available signal power) is then simply

$$G_c = \frac{4 g_g g_l}{\left(g_g + g_l + \frac{g_g g_l}{g_c}\right)^2}. \tag{1}$$

If the input and output impedances are equal, G_c approaches unity as g_g/g_c approaches zero. In this case, any thermal or shot noise sources in the nonlinear resistance will be completely mismatched from both input and output, so that the converter can be represented by a lossless, noiseless, matched four-terminal frequency translation network.

We are attempting to approach the performance of the ideal converter described above by using tunnel diodes as nonlinear resistances. An initial broadband converter ($f_{LO} = 780$ Mc, $f_i = 30$ Mc) had unity conversion gain, a radiometer noise figure of 2.5 db,[3] and was stable with input VSWR's exceeding 10:1 varied through all phases.

It is of interest to note, that both the minimum radiometer noise figure and the minimum conversion loss of a broadband positive resistance frequency converter (image frequency termination equals signal frequency termination) must exceed 3 db.[4] Also, for the tunnel diode used in our converter, $(I_0 R_d)_{\min}$ was about 1.2 (I_0 = dc current through diode, R_d = magnitude of negative resistance at bias point). The noise figure at high gain of a tunnel diode amplifier using this diode would exceed 3.5 db,[5] while the noise figure at high gain of a system using the converter together with the best commercially available 30-Mc IF amplifier (NF = 0.7 db) would be only 2.9 db.

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* Received by the IRE, May 17, 1961.

[1] E. W. Herold, "Frequency mixing in diodes," Proc. IRE, vol. 31, pp. 575–581; October, 1943.

[2] K. K. N. Chang, G. H. Heilmeier and H. J. Prager, "Low-noise tunnel-diode down converter having conversion gain," Proc. IRE, vol. 48, pp. 854–858; May, 1960.

[3] Passive circuit losses in front of the converter, amounting to 0.5 db are not included in the quoted gain and noise figure. These losses were due to the local oscillator input circuit and an IF rejection filter, and can, in principle at least, be eliminated by more careful design.

[4] E. W. Herold, R. R. Bush, and W. R. Ferris, "Conversion loss of diode mixers having image frequency impedance," Proc. IRE, vol. 33, pp. 603–609; September, 1945.

[5] M. E. Hines and W. W. Anderson, "Noise performance theory of Esaki (tunnel) diode amplifiers," Proc. IRE, vol. 48, p. 789; April, 1960.

Thin-Film Cryotrons*

On page 1568 of the paper by the above title, Smallman, *et al.*,[1] state that "the induced current in a tin (film) loop without a ground plane rapidly fell off to a *very low* value in a fraction of a second" (our italics). On page 1571, they state that "residual resistance is present in *many* no-ground-plane cryotrons, and it is significant that the addition of a ground plane completely eliminates it . . ." (our italics).

Hasty reading of these remarks might lead the reader to suppose that unshielded crossed-film cryotrons do not always become superconducting, and cannot be used reliably to store circulating currents. We feel sure that Smallman, *et al.*, did not mean to imply this. In the development by one of the authors, together with Bremer, of the unshielded crossed-film cryotron, which was published last year,[2] we found effects of the type mentioned by Smallman, *et al.*, when our devices were subjected to a field somewhat larger than that of the earth, directed at right angles to the film surface. Such fields can sometimes arise accidentally if ferromagnetic materials, such as steel clamps for instance, are used near the dewar. The magnetic field of the earth, however, did not affect the performance of our unshielded crossed-film cryotrons to any appreciable extent, nor did it prevent us from storing currents in unshielded cryotron circuits for several hours. In this connection, Crittenden, *et al.*,[3] report that current has been stored in unshielded tin and indium film circuits for many hours. No mention is made in their paper of any precautions to exclude the earth's magnetic field.

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* Received by the IRE, September 23, 1960; revised manuscript received, November 11, 1961.

[1] C. R. Smallman, A. E. Slade, and M. L. Cohen, "Thin-film cryotrons," Proc. IRE, vol. 48, pp. 1562–1582; September, 1960.

[2] V. L. Newhouse and J. W. Bremer, "High-speed superconductive switching element suitable for two-dimensional fabrication," *J. Appl. Phys.*, vol. 30, pp. 1458–1459; September, 1959.

It may therefore be concluded that unshielded tin and indium crossed-film cryotrons, persistors, etc. may be operated in the earth's magnetic field. Fields which are large enough to cause trouble may be cancelled out or screened out by any of the well-known methods. A method which is particularly suitable for work on superconductors is that of operating the circuits inside a cup of spun lead, placed in the liquid helium. This causes the lead to become superconducting and expel most of any stray magnetic fields present.

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[3] E. C. Crittenden, Jr., J. N. Cooper, and F. W. Schmidlin, "The 'persistor'—A superconducting memory element," Proc. IRE, vol. 48, pp. 1233–1246; July, 1960.

Are Electronics Engineers Educated?*

Webster defines engineering as "the art of designing, building, or using engines and machines, or of designing and constructing public works or the like." The concession is further made that engineering may be divided into the particular fields, within each of which the basic definition must be interpreted. One should logically expect, therefore, that a graduate of a good engineering school, with a degree in engineering, should be an engineer—"one who is versed in or practicing any branch of engineering." But is this really the case?

One needs only to attend any of the engineering conventions, symposia, section or professional group meetings to discover that there is an appalling lack of understanding among many of our younger engineers as to the things really important to "the art of designing." At these affairs, intelligent and sincere young men proudly describe their analyses, developments, and achievements. In many cases, original work *has* been done, and its author truly displays a good background of prior work. But too often the dissertation is a rediscovery of work already done, or describes hardware of marginal usefulness, and clearly demonstrates a lack of understanding of many things basic to engineering—"the art of designing."

In this situation is a reason why we have problems with missile reliability, circuit complexity, operational utility, high cost, or even engineering management. In this, the era of the cost-plus-fixed-fee contract, there is but slight financial incentive for industry to genuinely emphasize engineer training. If a young man must spend an extra several months researching the field to select the best components, or redesigning after the catastrophic field test, this is equally profitable to the company. Not only is the salary paid fully reimbursed, but a contribution to overhead helps further to retire the facility, even if no fee is earned. Engineer demand often places a company in the position of assigning engineers project responsibilities far beyond their training or experience. The senior, capable people have long since been removed from such mundane details as selecting the best relay, and now either revolve in the world of the "system" block diagram, the curtained offices and the policy meetings; or else, tiring of the gambit, have become independent consultants or launched their own companies. The public teat succors many a "research" program that, stripped of equations, is nothing more nor less than a learning curve for engineers who have not yet mastered "the art of designing."

In a profit-oriented company (and there are many such companies which refuse all but fixed-price contracts and are choosy about these), we have a similar situation, but for another reason. In these cases, the company cannot afford a plethora of engineers in the futile belief that somehow quantity will make up for quality, nor can it always afford the salary that competence demands. The company selects the best talent it can afford, trains it themselves, and piously hopes through all sorts of inducements to keep it around. But in these cases, the engineer soon finds himself with a work load which is some exponential function of his performance; the better job he does, the more he is assigned, until eventually he, too, cannot devote the time really required for "the art of designing" and must take chances and make guesses.

It is easy to find reasons, but hard to find excuses for this situation. Basically, the heart of the problem is *engineering education.* With a few notable exceptions, our engineering schools are not teaching, and never have taught, "the art of designing." They have taught "the science of analyzing." Throughout the average university curriculum, the emphasis is on *analysis* rather than *synthesis.* Given a circuit, what does it do? Yet the first task usually expected of the engineer is: given the specification, produce the design. The Laplace transform, important though it is, is of no help in deciding which of a dozen makes of capacitors to specify for a particular problem, or in hacking through the jungle of transistor and diode-type numbers. How many of our university catalogs today list courses dealing with what might be called "component sources," or, "who makes what, how good is it, how much does it cost, what are the quantity and OEM discounts, and how is it specified and bought?" How many new engineers even know where to look for product information beyond the magazine advertising? How many professors teach the perils of ground loops or excessive heater-cathode potentials; what are the best printed-circuit base materials; the relative merits of eyelets and plate-through; what constitutes a good solder connection; what plugs can be counted on to give trouble; where solid wire is preferable to stranded; and so on? How many engineering schools have test laboratories equipped with temperature and altitude chambers and random-and-sine vibration-testing equipment? How many show stroboscopic films of the jelly-like behavior of "rigid" components vibrating above their resonant frequencies? How many electronics engineers are taught in school the difference between a coarse and a fine thread, the hole size for a 4-36 screw, or, for that matter, the resistor, capacitor or diode color code? How many students get any appreciation of the *cost* of components as they learn their function? How many new graduates know the effects of stray fields from a transformer? How many know the practical side of what to expect from parasitic oscillations, even in pulse circuits, VR tubes, and Zener diodes, and how to avoid them? How many know what a MIL specification is? How many know how to make by themselves a limited patent search, or even of the existence of the *Patent Gazette?* All of these matters and painfully many more are, in general, left to industry to teach, or for the student to find out for himself, like sex—and to carry the analogy further, often the hard way as he watches his creation cremated on the launch pad. To the extent that industry is unable to do this training, unreliability is naively built into the design.

It is unfair to criticize education for sins of omission without recognizing its side too. Just where, in a four-year or six-year curriculum is there time for such mundane but necessary things, especially in view of the accelerated progress in the past twenty years? Certainly one should not drop the course in Laplace transform in favor of these things. Where does the school obtain qualified professors with practical (and successful) design experience, and how can they be motivated to teach such subjects adequately, with altruistic indifference to the salary received? How can the expense of environmental test equipment be fitted into the budget? And, after all, should an academic institution of "higher learning" teach the things that are really "lower learning"? Of course these are legitimate questions, but they do have answers.

While adequate finance may not be a panacea, it is certainly a necessary remedy to part of the problem. The schools than can afford modern equipment and adequate salaries, and who have working arrangements with nearby industry for laboratory training and summer employment sessions, are turning out the best engineers. Summer periods are an indoctrination into "things

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* Received by the IRE, February 7, 1961; revised manuscript received, March 23, 1961.

practical," so essential to "the art of designing." It is to the advantage of both industry and the taxpayer to give generous financial support for such needs. Better engineers will ultimately result, and the investment will be returned many fold.

Additions to engineering curricula of required courses dealing with these practical subjects are needed, even if at the expense of fewer hours of student leisure. Existing courses need greater emphasis on synthesis—working from specifications—not simply in class-A amplifiers or emitter followers, but in digital and RF systems and a host of more complex subjects. The practical side should be taught along with the theory. The student should commit to memory the standard values of 5 per cent and 10 per cent resistors and be required to use these in his designs, and recompute performance in a tolerance (and temperature) analysis. His problem sets should require detailed component selection and specification of critical part locations and lead lengths, hole sizes, types of plugs for interconnections, and so on. Grading could be on how his design would probably withstand temperature, humidity, vibration, shock, corrosion, and whether it would be economical and reliable. Perhaps most of all, the student should be instructed to locate alternate units already commercially available that might satisfy the basic requirements so that he will know whether, in fact, he should be designing such a unit at all except for practice.

We write about engineers who cannot spell, write, or speak in public, and so on, but these things may be secondary to "the art of designing." Such deficiencies are easily tolerable in a man who can turn out a solid, producible, economical, trouble-free, profitable, and useful product. The archives are full of scholarly technical reports on projects long deceased because of poor design.

Only with practical training, in school, government or industry, and preferably all three, can it truly be said that the engineer is *educated* and is "one who is versed in or practicing any branch of engineering—the art of designing."

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A Note on Sugai's Class of Solutions to Riccati's Equation*

In this correspondence, it will be shown that the solution of Riccati's differential equation can be found from the solution of two associated Bernoulli equations provided the coefficients of the Riccati equation satisfy certain relationships to be specified later. This work generalizes the technique presented by Sugai[1] in a recent note. It is accomplished by using a more general transformation of the dependent variable than that used by Sugai. In this note, the notation of Ince[2] is used.

The Riccati differential equation reads

$$\frac{dy}{dx} + \psi y^2 + \phi y + \chi = 0. \tag{1}$$

The transformation proposed here is given by

$$y(x) = \frac{c_1(x)v'(x) + c_2(x)v(x)}{c_3(x)v'(x) + c_4(x)v(x)}, \tag{2}$$

where the prime denotes differentiation with respect to x. Substituting the expression for $y(x)$ in (2) into (1), it is seen that $v(x)$ satisfies the following second-order equation:

$$vv''Q_1 - (Q_1 + Q_4)(v')^2 - Q_3vv' - Q_2v^2 = 0, \tag{3}$$

where

$$\begin{aligned} Q_1 &= c_1c_4 - c_2c_3 \neq 0 \\ Q_2 &= c_2c_4' - c_2'c_4 - c_2^2\psi - c_2c_4\phi - c_4^2\chi \\ Q_3 &= c_1c_4' - c_1'c_4 + c_2c_3' - c_2'c_3 \\ &\quad - (c_1c_4 + c_2c_3)\phi - 2c_1c_2\psi - 2c_3c_4\chi \\ Q_4 &= c_1c_3' - c_1'c_3 - c_1^2\psi - c_1c_3\phi - c_3^2\chi. \end{aligned}$$

Eq. (3) will be a linear second-order equation if the condition

$$Q_1 + Q_4 = 0 \tag{4}$$

can be enforced. This condition leads to either one of the following two Riccati equations:

$$c_1' + \frac{\psi}{c_3}c_1^2 + \left(\phi - \frac{c_3'}{c_3} - \frac{c_4}{c_3}\right)c_1 + c_2 + c_3\chi = 0 \tag{5a}$$

$$c_3' - \frac{\chi}{c_1}c_3^2 - \left(\phi + \frac{c_1'}{c_1} + \frac{c_2}{c_1}\right)c_3 + c_4 - c_1\psi = 0. \tag{5b}$$

These equations reduce to Bernoulli's equation, which can be solved in closed form,[3] if in (5a) the condition

$$c_2 = -c_3\chi \tag{6a}$$

is met, or if in (5b) the condition

$$c_4 = c_1\psi \tag{6b}$$

is met. Thus (5a) or (5b) reduces to Bernoulli's equation and c_1 or c_3 can be determined in closed form.

The condition given in (6a) is satisfied by the first transformation given by Sugai in (4) of his paper. The second given in (6b) is satisfied by the transformation given by Sugai in (5) of his paper.

Now the problem has been reduced to solving the following differential equation:

$$Q_1v'' - Q_3v' - Q_2v = 0. \tag{7}$$

The fact that (1) is equivalent to a second-order linear equation is well known.[4] Hence, in order to benefit from the transformation in (2), one requires that Q_2 must also vanish subject to either the condition in (6a) or (6b). The vanishing of Q_2 subject to (6a) and (6b) is given in (8a) and (8b), respectively.

$$c_3c_4' - c_3'c_4 - \left(\phi + \frac{\chi'}{\chi}\right)c_3c_4 + c_3^2\chi\psi + c_4^2 = 0 \tag{8a}$$

$$c_1'c_2 - c_1c_2' - \left(\phi - \frac{\psi'}{\psi}\right)c_1c_2 - c_1^2\chi\psi - c_2^2 = 0. \tag{8b}$$

It is noted that (8a) is a Riccati equation in either c_3 or c_4, and (8b) is a Riccati equation in either c_1 or c_2, and thus, it is of little value to specify ψ, ϕ, χ. However, at this point it is convenient to point out the results of Sugai's work. It is seen by substitution in (8a) that if one lets

$$c_1 = 0, \quad c_2 = -\chi, \quad c_3 = 1, \quad c_4 = \phi, \tag{9a}$$

which are the conditions in Sugai's transformation given in (4) of his note, then one deduces the condition given in (8) of his note. If one lets

$$c_1 = 1, \quad c_2 = -\phi, \quad c_3 = 0, \quad c_4 = \psi, \tag{9b}$$

then one has the transformation suggested by Sugai in (5) of his note. In this case one deduces the condition in (9) of his note.

New relationships can be derived from the generalized transformation defined in (2) through the study of (8a) and (8b). The study will be facilitated by rewriting (8a) and (8b) in the following forms, namely:

$$\chi' - \frac{c_3\psi}{c_4}\chi^2 + \left(\phi - \frac{c_4}{c_3} + \frac{c_3'}{c_3} - \frac{c_4'}{c_4}\right)\chi = 0 \tag{10a}$$

$$\psi' - \frac{c_1\chi}{c_2}\psi^2 - \left(\phi + \frac{c_2}{c_1} + \frac{c_2'}{c_2} - \frac{c_1'}{c_1}\right)\psi = 0. \tag{10b}$$

Thus it is seen that (10a) and (10b) are Bernoulli's equations in terms of χ and ψ, respectively. The solution of an equation of the form

$$\frac{dz}{dx} + q_1(x)z^2 + q_2(x)z = 0$$

is also a solution of the equation[3]

$$\frac{d}{dx}\left(\frac{1}{z}\right) = q_1(x) + q_2(x)\left(\frac{1}{z}\right).$$

Thus, for example, in (10a), one can specify c_3 and c_4 in any convenient manner, and since (10a) can be solved in closed form, the functional relationship between ψ, ϕ, χ necessary to obtain a solution of (1) by these techniques can be found. The coefficients c_1 and c_2 are now determined by the conditions specified in (5a) and (6a).

Thus, it has been shown that the solution of a Riccati equation can be found by solving two Bernoulli equations provided ψ, ϕ, χ and the auxiliary coefficients are related as in (10a), (5a) and (6a), or (10b), (5b) and (6b).

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* Received by the IRE, March 27, 1961.

[1] I. Sugai, "A new exact method of nonuniform transmission lines," Proc. IRE, vol. 49, pp. 627–628; March, 1961.

[2] E. L. Ince, "Ordinary Differential Equations," Dover Publications, Inc., New York, N. Y., pp. 23–25; 1956.

[3] *Ibid.*, pp. 22, 24.

[4] *Ibid.*, p. 23.

A New RMS Describing Function for Single-Valued Nonlinearities*

Klotter[1] and Prince[2] have at one time or another proposed various unconventional describing functions, but these have not found widespread use because they do not, in general, provide the accuracy of the conventional describing function. The present authors have also looked into a number of other describing functions based on minimizing the average value of error between the fundamental of the output of the nonlinearity for a sine-wave drive and the absolute value of error, etc. Of course, it is apparent that as the linear element of the closed loop tends toward a perfect low-pass filter, the error of the conventional describing function tends towards zero. It is possible, however, that an unconventional describing function could provide better accuracy for many practical systems since perfect filtering is unrealistic.

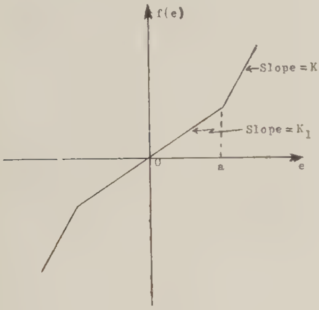


Fig. 1.

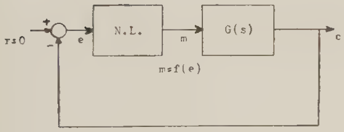


Fig. 2.

The authors propose that for single-valued, instantaneous nonlinearities, a possibly superior describing function is obtained by equating the rms value of the equivalent output sine wave of fundamental frequency to the rms value of the actual nonsinusoidal output of the nonlinear element in response to a sine-wave drive. This might be justified on an equivalent energy basis. The definition is thus,

$$K_{\text{eq}} \triangleq \left\{ \frac{\dfrac{1}{2\pi}\displaystyle\int_0^{2\pi} [f(E \sin \theta)]^2 d\theta}{\dfrac{1}{2\pi}\displaystyle\int_0^{2\pi} (E \sin \theta)^2 d\theta} \right\}^{1/2}, \qquad (1)$$

where

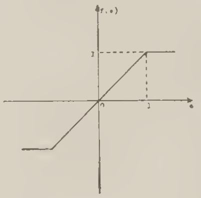
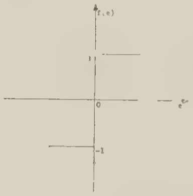
$E \sin \theta \triangleq$ input to the nonlinearity

$f(E \sin \theta) \triangleq$ output of the nonlinearity.

For instantaneous nonlinearities, the phase shift through the element will be zero. Consider the nonlinearity shown in Fig. 1. There,

$$f(e) = \begin{cases} k_2(e-a) + k_1 a & (e \geq a) \\ k_1 e & (-a < e < a) \\ k_2(e+a) - k_1 a & (e \leq -a). \end{cases}$$

TABLE I

N. L.	$G(s)$	Method	Predicted Amplitude of Oscillations	Percentage Error	Predicted Period of Oscillations	Percentage Error
	$\frac{10}{s(s+1)^2}$	Describing Function	6.30	5.95	6.28	1.67
		Proposed rms DF	6.80	1.49	6.28	1.67
		Experimental	6.70		6.38	
	$\frac{5}{s(s+1)^3}$	Describing Function	7.45	8.25	10.90	2.68
		Proposed rms DF	7.75	4.55	10.90	2.68
		Experimental	8.12		11.20	
	$\frac{2}{s(s+1)^4}$	Describing Function	4.55	3.19	15.70	3.29
		Proposed rms DF	4.75	1.06	15.70	3.29
		Experimental	4.70		15.20	
	$\frac{10}{s(s+1)^2}$	Describing Function	6.35	7.85	6.28	1.67
		Proposed rms DF	7.07	2.61	6.28	1.67
		Experimental	6.89		6.38	
	$\frac{5}{s(s+1)^3}$	Describing Function	7.15	5.92	10.90	0.925
		Proposed rms DF	7.07	4.60	10.90	0.925
		Experimental	7.60		10.80	
	$\frac{2}{s(s+1)^4}$	Describing Function	4.45	4.30	15.60	0.636
		Proposed rms DF	4.95	6.45	15.60	0.636
		Experimental	4.65		15.70	

For this nonlinearity, (1) becomes

$$\begin{aligned} K_{\text{eq}} = \Bigg\{ & k_2^2 + \frac{2}{\pi}(k_1^2 - k_2^2) \\ & \cdot \left[\sin^{-1}\frac{a}{E} - \frac{a}{E}\sqrt{1 - \frac{a^2}{E^2}} \right] \\ & + \frac{8}{\pi} k_2(k_1 - k_2) \frac{a}{E} \sqrt{1 - \frac{a^2}{E^2}} \\ & + 2(k_1 - k_2)^2 \frac{a^2}{E^2}\left(1 - \frac{2}{\pi}\sin^{-1}\frac{a}{E}\right) \Bigg\}^{1/2} \end{aligned}$$

$$(E > a), \qquad (2)$$

which is somewhat more complex than the conventional describing function for the same nonlinearity

$$N = k_2 + \frac{2}{\pi}(k_1 - k_2)$$

$$\cdot \left[\frac{a}{E}\sqrt{1 - \frac{a^2}{E^2}} + \sin^{-1}\frac{a}{E} \right] \quad (E > a).$$

For the relay with dead band, the rms describing function (1) becomes

$$K_{\text{eq}} = \left\{ \frac{2}{\pi} \frac{M^2}{E^2} \left[\pi - 2 \sin^{-1} \frac{B}{2E} \right] \right\}^{1/2} \quad \left(E > \frac{B}{2} \right), \qquad (3)$$

and the conventional describing function is

$$N = \frac{4}{\pi} \frac{M}{E} \sqrt{1 - \frac{B^2}{4E^2}} \quad \left(E > \frac{B}{2} \right).$$

An analog computer study of a number of systems has been made to establish an initial feeling for the accuracy of the rms describing function. Two nonlinearities have been considered: 1) saturation or limiting for which the rms describing function is a special case of (2), and 2) the perfect relay, a special case of (3). The linear elements involved are of the third, fourth and fifth order. As might be anticipated, the conventional describing function improves as the filtering becomes heavier, but the rms describing function presents a significant improvement for the lower-order cases. A block diagram of the configuration is shown in Fig. 2 and the results are summarized in Table I. Work is proceeding on the application of this new describing function to non-single-valued nonlinearities.

Thanks are due D. C. Fosth for analog computer programming.

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[1] K. Klotter, "An extension of the conventional concept of the describing function," *Proc. Symp. on Nonlinear Circuit Analysis*, Polytechnic Inst. of Brooklyn, Brooklyn, N. Y., vol. 6; 1956.

[2] L. T. Prince, Jr., "A generalized method for determining closed-loop frequency response of nonlinear systems," *Trans. AIEE*, pt. 2, vol. 73 (*Applications and Industry*) pp. 217–224; September, 1954.

A Proposed Test of the Constancy of the Velocity of Light*

Einstein's definition of simultaneity and also all accurate measurements that have ever been made of the velocity of light are based upon the assumption that the reflection (by a mirror that is at rest in the observer's frame) of a light signal which is traveling over a return path occurs precisely at the half time for the journey. Because the one-way velocity of light has never been accurately measured,[1] this assumption has never been subjected to a direct test. Stated in another way, it is postulated that the observer's relative space is isotropic to the propagation of light; and this is the underlying and untested assumption upon which the special theory of relativity rests.[2] Recent developments have raised serious questions as to the validity of this postulate.[3,4] I believe, therefore, that it is highly desirable for a direct test of Einstein's concept of simultaneity and of his second postulate to be made at this time, especially since such a test now appears possible with modern techniques.

I offer, by way of example, that two identical maser-controlled clocks, each fashioned to store information on video tape or some similar device accurate to one thousandth of a microsecond, can be first synchronized, while together, by means of identical marker signals on the two tapes, and then can be transported to locations about 18.6 miles apart. The two clocks are hereby stationed 100 microseconds apart by light signal, so that the velocity of light can be timed accurately one-way to ±one mile per second. Selected marker signals at station A are arranged so as to fire a strobe light toward station B, and the tape at station A is marked electronically to indicate each firing. The light signal is detected at station B by a photocell, which marks tape B and simultaneously fires a second strobe light toward station A. The receipt of the return signal is recorded by a photocell, which completes the cycle. Other cycles can be performed as needed.

Upon the assumption that light is some unspecified form of wave propagation, the velocity of the solar system in the universe should produce a first-order effect of V/C on the time required for light to pass in the two directions, when the light signal and the vector V are parallel. This effect equals the time difference in the two directions divided by the total time; i.e.,

$$\frac{t_2 - t_1}{t_2 + t_1} = \frac{v}{c} = \frac{\Delta t}{t}.$$

To this end, the apparatus should be oriented so that at some time during the day it is tangent to our probable orbit about the supergalactic center, located in Virgo. In this case, V should be on the order of 1000 miles per second, and should hence be easily detectable. However, if Einstein's postulate is correct, or if light behaves ballistically, there will be a null effect and relative space will have been proved isotropic to the propagation of light. In this event, a separate, but similar experiment would have to be conducted to decide between Einstein's postulate and the ballistic-like considerations which have been introduced by Prof. Dingle.[2]

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* Received by the IRE, March 20, 1961.

[1] M. Ruderfer, "Relativity: blessing or blindfold?" Proc. IRE (Correspondence), vol. 48, pp. 1661–1662; September, 1960.

[2] H. Dingle, "A possible experimental test of Einstein's second postulate," *Nature*, vol. 183, p. 1761; June, 1959.

[3] H. Dingle, "Relativity and electromagnetism: an epistemological appraisal," *Phil. Sci.*, vol. 27, pp. 233–253; July, 1960.

[4] P. M. Rapier, "Comments on the article, 'Relativity and the mechanical engineer,' " (by B. D. Mills, Jr.), *Mech. Engrg.*, vol. 82, pp. 91–92; August, 1960.

Notes on the Structure of Logic Nets*

Introduction

The purpose of this note is to present an elementary approach to a theory of the role of structure in logic nets and to give examples of some simple applications. We are primarily, although not exclusively, interested in "cellular" or "honeycomb" structures which have a) approximately the form of three-dimensional regular lattices, b) a uniform type of elementary component in a single lattice, and c) simply connected elementary components, *i.e.*, components connected only to adjacent components, or possibly, if located on the periphery, to "system" inputs or outputs. Such structures are termed "peripheral access lattices" or simply PAL's. The composite structure and its behavior, observed at the peripheral connections, is referred to as macrostructure while its constituent elementary components are referred to as microstructures or microcomponents. We are especially concerned with the range of possible macroscopic behavior for nets having a *fixed basic structure but some variability in microscopic behavior.*

Variability and the Basic Theorem of Composite Structures

Let N represent the number of different possible modes of behavior of a multistable logic structure. Variations in behavior are presumed to correspond to different possible quasi-stable states in which the structure may exist, according to its past history, treatment or conditioning.

If a macrostructure consists of an assembly of n microstructures, then the number of different system-states equals the product of all component state numbers, and thus, obviously,

$$N_{\text{macro}} \leqq \prod^{n} (N_{\text{micro}})_i. \qquad (1)$$

The equality applies if, for every different arrangement of microstates, the macrostructure responds differently, as observed at its periphery. If we define

$$C = \log_2 N, \qquad (2)$$

then, from (1),

$$C_{\text{macro}} \leqq \sum^{n} (C_{\text{micro}})_i. \qquad (3)$$

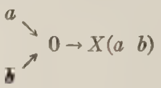
C may properly be called the equivalent structural information content and is numerically equal (if an integer) to a minimum number of binary digits required to specify, identify, or describe the behavior or response function of a structure.

Maximum Capacity of Binary Devices

For a unilateral device having n_i binary inputs and n_o binary outputs, which are functionally dependent on the inputs,

$$C \leqq 2^{n_i} n_o \qquad (4)$$

The equality applies to a structural unit capable of assuming any describable functional dependence of the output pattern on the input pattern and is essentially the dimensionality of the associated "truth table" or generalized Venn diagram. Such a device is termed a "universal" computer. For example, a unit having two inputs and one output as shown



has a maximum structural capacity of 4 bits. If it has such capacity it must be capable of performing as an "and gate," "or gate," "nor gate," "exclusive-or-gate" and all such possibilities (16 in all) including such things, usually considered somewhat trivial in the logical design of computers, as $X=0$, $X\equiv 1$, $X\equiv a$, $X\equiv \bar{a}$, $X\equiv b$, or $X\equiv \bar{b}$. With $n_i=1$ and $n_o=2$ the maximum capacity is likewise 4 bits.

Minimum Size of Universal Binary Machines

If a binary macromachine consisting of a number of identical binary microcomponents is to be universal, then from (3) and (4),

$$n \geq 2^{(N_i - n_i)} \left(\frac{N_o}{n_o}\right). \qquad (5)$$

As an example of the implications of this result, consider the structure shown in Fig. 1 where a microcomponent is presumed to be located at each vertex. If the components are universal elements, $(C_{\text{micro}})_i = 4$ bits and, hence,

$$\sum^{n-60} (C_{\text{micro}})_i = 240 \text{ bits.}$$

But,

$$2^{N_i} N_o = 2^6 \cdot 6 = 384 \text{ bits.}$$

Thus, it is fundamentally impossible for this macrostructure to be universal. In other words, there are apparently some response functions which can be described for $N_i=6$ and $N_o=6$ but which cannot be realized

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* Received by the IRE, February 7, 1961; revised manuscript received, March 17, 1961.

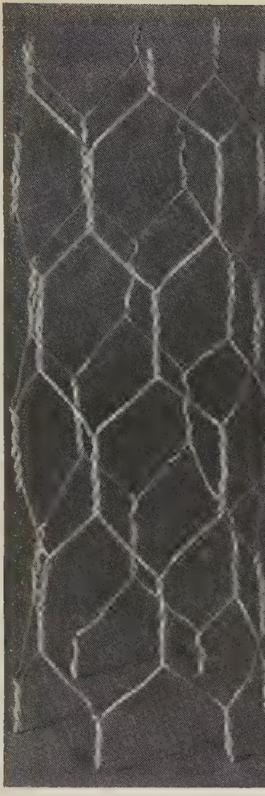

Fig. 1.

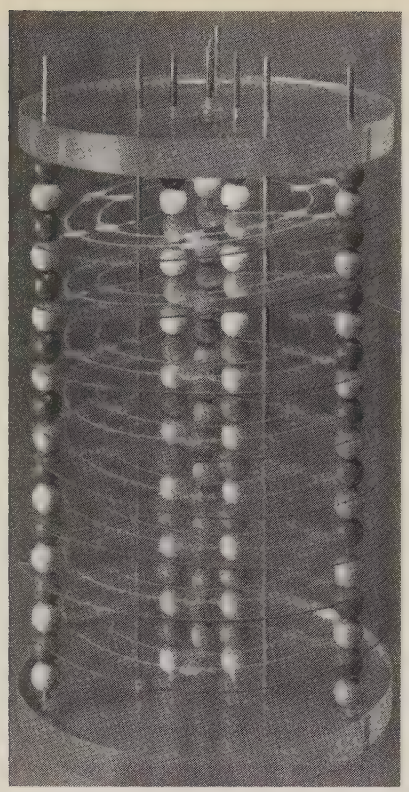

Fig. 2.

with this internal structure and connectivity regardless of how we may choose the behavior of the (binary) internal components. This particular type of structure has a number of interesting special properties and has been the subject of further intensive study.

THE CLOSURE RULE

A useful theorem in dealing with logic nets is based on the assumption that there are no loose ends, *i.e.*, every input connection to a microcomponent is either a peripheral input to the macrosystem or the output of some microcomponent and that every output of a microcomponent either terminates as an input to some microcomponent or as a peripheral output of the macrosystem. Then, by counting internal connections,

$$\sum^{n} n_i - N_i = \sum^{n} n_o - N_o.$$

When N_i and N_o are much less than $\sum n_i$ and $\sum n_0$ (*i.e.*, many more "internal" connections than peripheral connections), this reduces to

$$\langle n_i \rangle = \langle n_o \rangle, \tag{7}$$

where $<n_i>$ and $<n_o>$ are respectively the *average* number of inputs and outputs per microcomponent. Under these conditions, this might suggest, for example, that a net partially composed of microcomponents for which $n_i=2$ and $n_o=1$ might be completed with approximately an equal number of components for which $n_i=1$ and $n_o=2$:

$$\begin{tikzcd} & X(a) \\ a \arrow[r] & 0 \arrow[u] \arrow[d] \\ & Y(a). \end{tikzcd}$$

Another class of structures of interest is that corresponding to a simply connected lattice of closest-packed spheres; for such a lattice,

$$n_i + n_o = 12 \tag{8}$$

for every component except those on the periphery. Therefore, from the modified Closure Rule (7)

$$\langle n_i \rangle = \langle n_o \rangle = 6. \tag{9}$$

If we let $n_i \equiv n_o \equiv 6$, for every component, $C_{\text{micro}} = 384$ bits/component as shown previously.

POSSIBILITIES AND PROBABILITIES

Various workers have concerned themselves with calculating and describing theoretical constraints on macrosystem behavior when the constituent microcomponents are constrained in certain special ways. As yet, there has appeared very little analysis involving structural contraints as well. As a simple example, it is probably well-known that an assembly exclusively comprised of any number of "and-gates" and "or-gates," and having just two peripheral inputs (a, b) and one peripheral output $[X(a, b)]$ can behave macroscopically only in the trivial ways. $X \equiv 0$, $X \equiv a$, or $X = b$ or else either as an "and-gate" or as an "or-gate." What may not have been demonstrated is that, if the trivial responses are structurally impossible and if the microcomponent response functions are chosen at random with $p_{\text{and}} = p_{\text{or}} = \frac{1}{2}$ then the macrosystem response probabilities are likewise $P_{\text{and}} = P_{\text{or}} = \frac{1}{2}$. This result is a direct consequence of De Morgan's theorem. This type of analysis of a logic net is directly analogous to the basic aims of physical statistics or statistical mechanics.

The model shown in Fig. 2 represents a machine for which $N_i = 3$, and $N_o = 3$. Hence, $C \leq 2^3 \cdot 3 = 24$ bits. The machine represented actually achieves the theoretical maximum capacity of 24 bits (approximately 16,000,000 different response functions) using just 24 switches (in addition to a fixed section of "nor" elements) and, hence, has a total microcapacity of just 24 bits. Furthermore, if for each bistable component, $P_{\text{open}} = P_{\text{close}} = \frac{1}{2}$, then the probability of occurrence of each possible response function is the same and this machine is, therefore, "structurally homogeneous."

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Suppression of Emission from Portions of Barium-Activated Tungsten Dispenser Cathodes and Adjoining Electrodes*

It is often desirable to suppress the emission from portions of cathode surfaces in order to generate electron beams of special shape and also to prevent electron emission from cathode supports and from auxiliary electrodes in close proximity to the cathode. Both objectives are difficult to achieve because most metals become activated by cathode evaporation and migration products.

A technique[1] has been developed to suppress the electron emission from portions of barium-activated tungsten dispenser cathodes[2-5] and from hot tungsten and molybdenum surfaces close to such dispenser or oxide-coated cathodes. The technique consists in carburizing the areas to be rendered nonemitting by completely immersing the part to be treated, save for necessary masks, in finely divided graphite powder and heating for 5 to 15 minutes at a temperature in the range 1500 to 1800°C in an atmosphere of hydrogen. Carbides of molybdenum and tungsten are formed at the treated surfaces for depths of some tens of microns.

The emission from barium-activated dispenser cathodes is reduced by this process by two or more orders of magnitude in the usual operating range of these cathodes (*e.g.*, 900 to 1200°C. The lower limit can be further reduced if the cathode evaporation rate is sufficiently small.) That the inhibition of emission arises solely from the presence of the carbide layer can be demonstrated by grinding the emitter sur-

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* Received by the IRE, June 29, 1961.

[1] R. Levi, "Carburization of dispenser cathodes," U. S. Patent No. 2,972,078; February, 1961.

[2] H. J. Lemmens, M. J. Jansen, and R. Loosjes, "A new thermionic cathode for heavy loads," *Philips Tech. Rev.*, vol. 11, p. 341–350; June, 1950.

[3] R. Levi, "New dispenser type thermionic cathode," *J. Appl. Phys.*, vol. 24, p. 233; February, 1953.

[4] R. Levi, "Improved impregnated cathode," *J. Appl. Phys.*, vol. 26, p. 639; May, 1955.

[5] P. P. Coppola and R. C. Hughes, "A new pressed dispenser cathode," PROC. IRE, vol. 44, pp. 351–359; March, 1956.

face down to a depth exceeding that of the carbided region, whereupon the full emission density of the cathode is recovered. This presents another possibility, in addition to masking, for selective carburization of cathode surfaces. The inhibition of emission from dispenser cathodes persists for times of the order of 10^3 to 10^4 hours, the higher values applying at lower cathode temperatures. Return of emission coincides with complete disappearance of the carbide layer from the surface of the cathode.

In the case of thin adjoining electrodes of tungsten and molybdenum, provided that embrittlement is not a serious concern, carburization to a depth comparable to the electrode thickness yields negligible emission relative to that from barium-activated tungsten[6] or molybdenum[7] surfaces for times much longer than those observed in inhibited dispenser cathodes. Since the evaporant from these dispenser cathodes is constituted of Ba and BaO,[6,8] carburized tungsten and molybdenum electrodes in close proximity to oxide-coated cathodes will also exhibit emission suppression, provided that they attain a temperature approaching that of the cathode.

The carburization technique has been applied successfully to the generation of hollow beams and to the suppression of emission from cathode supports and auxiliary electrodes such as beam focusing electrodes, disk-shaped grids, accelerating anodes, and guard electrodes. Cathodes containing beam focusing or guard electrodes can be prepared as a single solid structure. A notable success has been the elimination of emission from molybdenum end hats in magnetron cathodes.

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[6] E. S. Rittner, R. H. Ahlert, and W. C. Rutledge, "Studies on the mechanism of operation of the L-cathode (I)", *J. Appl. Phys.*, vol. 28, pp. 156–166; February, 1957.

[7] E. S. Rittner and R. H. Ahlert, "Thermionic emission from barium-activated molybdenum," *J. Appl. Phys.*, vol. 29, pp. 61–63; January, 1958.

[8] E. S. Rittner, W. C. Rutledge, and R. H. Ahlert, "On the mechanism of operation of the barium aluminate impregnated cathode," *J. Appl. Phys.*, vol. 28, pp. 1468–1473; December, 1957.

Transmission Line Model*

In the consideration of transmission line problems, a type of line can be hypothesized which has some interesting characteristics, and which may be used also in theoretically studying radio-wave transmission through various homogeneous isotropic media. Some radio engineers have found the procedures hereafter described to be more convenient in the handling of wave transmission problems through these media than the use of field theory.

This hypothetical transmission line is of the coaxial type, is infinitely long, uses conductors having zero resistance, and the region between conductors is a vacuum; also the ratio of the inner diameter of the outer conductor to the outer diameter of the inner conductor is chosen as equal to $e^{2\pi}$ (that is, 535.5). (In further discussion, the rationalized mks system of units is employed.) From conventional coaxial-line formulas for the fundamental transmission mode, certain properties of the line may be computed. When computed thereby, the capacitance per meter length is found to be the same as the permittivity of free space (or 8.85×10^{-12} farads per meter), the inductance per unit length is found to be the same as the permeability of free space (or 1.257×10^{-6} henries per meter), and the characteristic impedance of the line is found to be the same as the intrinsic impedance of free space (or 376.7 ohms, resistive). Moreover, the propagation velocity of a radio wave along the line is the same as that of light in a vacuum. Phase changes in voltages and currents, with time, along the line, resemble those occurring in the respective counterpart electric and magnetic fields during the passage of a plane radio wave through free space, and the wave is not attenuated during transmission along the line. Thus, the accessible end of this long-coaxial line provides a two-terminal electrical network which simulates in several ways the transmission of a plane radio wave through free space.

This hypothetical line may be used in various calculations involving radio-wave transmission through homogeneous isotropic media other than free space. To this end, let it be supposed that the space between the line conductors is completely filled with the particular substance under consideration, rather than being evacuated. Moreover, let it be assumed that the permittivity, permeability and specific conductivity of the material to be examined are known quantities at the frequency of interest. Then, the capacitance, inductance, and conductance per unit length of the filled line may be readily calculated. It is pointed out that the line conductance per unit length is numerically the same as the specific conductivity of the material filling the line, in mhos per meter.

From data on the capacitance, inductance and conductance per unit length of the line, when filled with the chosen medium, conventional coaxial-line formulas for wave transmission may then be used to determine, for the medium of interest, such quantities as wave-propagation velocity, attenuation, and intrinsic impedance. This follows, since the electromagnetic field within the line is confined entirely to the substance filling the line, and does not enter the perfectly conducting coaxial members.

This hypothetical line will now be used, illustratively, to determine certain electromagnetic properties for plane waves in sea water at frequencies less than 10^6 cycles (1 Mc). Initially, sea water is considered to have the same permeability as free space; a specific conductivity of 4 mhos per meter; and a permittivity of 708×10^{-12} farads per meter, or for the latter quantity, 80 times that of free space. From such data, the inductance, capacity and conductance per unit length immediately follow for the "sea water" line, as already explained. In this case, it is also noted that the susceptance of the shunt-capacitance path in a unit length of line is only 0.11 per cent of that of the conductance thereof at a frequency of 10^6 cycles; hence, the admittance of a unit length of line may be considered the same as the conductance thereof at frequencies less than just cited, or 4 mhos per meter. This allows further simplification of coaxial-line formulas for the problem at hand.

Accordingly, certain electromagnetic properties of plane waves in sea water may be computed as follows:

$$\alpha = 0.0173\sqrt{f(\sigma - 4.45f\cdot 10^{-9})} \cong 0.0173\sqrt{f\sigma} \tag{1}$$

$$\eta = \left[0.00281\sqrt{\frac{f}{\sigma}}\right]\sqrt{j} \tag{2}$$

$$v = \frac{3162\sqrt{f}}{\sqrt{\sigma + 4.45f\cdot 10^{-9}}} \cong 3162\sqrt{\frac{f}{\sigma}} \tag{3}$$

where α is the wave attenuation, in decibels per meter; f is the frequency, in cycles per second; σ is the specific conductivity, in mhos per meter; v is the wave velocity, in meters per second; η is the intrinsic impedance, in ohms; and j is the operator, $\sqrt{-1}$. Certain reference material[1] may be helpful to others who wish to derive the above equations.

It should be remembered that the formulas shown above are somewhat restricted; that is, they are applicable at frequencies less than 10^6 cycles and with a sea-water specific conductivity not appreciably less than 4 mhos per meter. For example, at a frequency of 2×10^4 cycles (20 kc), and with sea water having a specific conductivity of 4 mhos per meter, the above formulas show that the attenuation is 4.9 db per meter, the propagation velocity is 223,600 meters per second, and the intrinsic impedance is $0.199\ \angle 45°$ ohms.

The formulas shown above are identical with those deduced by field theory under similar restrictions, and have been known for decades. However, many practicing radio engineers are more adept in using transmission line theory and equations than in employing field theory. Hence, the transmission line model approach to solution of such problems is suggested as being helpful.

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* Received by the IRE, March 27, 1961.

[1] The equations cited follow substitution in, and permissible simplification of, the appropriate transmission line equations shown in the handbook, "Reference Data for Radio Engineers," Internatl. Telephone and Telegraph Corp., New York, N. Y., 4th ed., p. 552; 1956. The expression for α of (1), is deduced from the expression for α in the handbook cited, but the unit of (1) is decibels per meter, whereas in the handbook, the unit is nepers per meter. The η of (2) is arrived at from the expression for Z_0 in the handbook. In (3), v is actually the ratio of $2\pi f$ to β, the expression for β being given in the handbook. In substituting in the handbook equations, the term R, the line resistance per unit length, is taken as zero in value, for the line conductors have no ohmic loss.

Antenna Siting Tests at 3480 and 9640 Mc on a 173-Mile Tropospheric Scatter Path*

During the past three years, scatter propragation measurements have been carried out at 3480 and 9640 Mc over a 173-mile path in southern England using transmitters situated at Start Point, Devon. In addition to the usual propagation measurements made at Wembley, Middlesex, which have been reported elsewhere,[1,2] the signal at each frequency was recorded for a short period at an unfavourable site 1.5 miles from the Wembley terminal. This site, at Kenton, Middlesex, was shadowed by Harrow-on-the-Hill at a distance of 1.8 miles. The angular path distances, θ, of the Start Point-Wembley and Start Point-Kenton paths were respectively 26 and 54 milliradians. The *S*-band signal was recorded simultaneously at the two receiver sites for about 10 days during June, 1959, while a similar period of recording was carried out at *X* band in January, 1960. In all cases, the signal level was measured in terms of the half-hourly median value of the system transmission loss estimated from low speed pen records of the received transmission. The antennas used on the transmitters and receivers were 8-foot paraboloids. The median value of the decibel difference in level at Wembley and Kenton was, at both *S* and *X* band, about 16 db, very close to the value predicted by Norton, *et al.*,[3] on the basis of the angular distance of the paths. Following a suggestion by D. Williams, of SRDE, these measurements have now been examined in more detail and it is the purpose of this note to describe briefly the results.

An analysis was carried out to see how the difference in signal levels measured at the two sites varied as a function of the system transmission loss, *L*, of the Start Point-Wembley path. This is illustrated for *S* and *X* band respectively in Figs. 1 and 2. The graphs were obtained by grouping the data for each frequency according to the value of *L*, a grouping interval of 1 db being used. Each of the points through which the curve is drawn represents the arithmetic mean of the measured db differences in level lying within one interval; the second curve in each figure gives the number of measurements available to average in each case. The plot of average difference in level against *L* is seen to be very similar at the two frequencies. At the higher signal levels there is a region where the difference is fairly constant and of the order of 20 db; as *L* increases a point is reached at which the average difference starts to fall and beyond this decreases at an approximately constant rate (0.7 db/db at *S*-band and 0.8 db/db at *X* band). It is interesting to note, that the transition level from a constant to a decreasing difference occurs at both *S* and *X* band at about 12 or 13 db above the median value of the signal for the time of the year in which the respective measurements were made. The spread of the measurements within each interval of *L*, as measured by their standard deviation, did not appear to vary significantly with level; the average value of the standard deviation was about 2.6 db at *S* band and 3.2 db at *X* band.

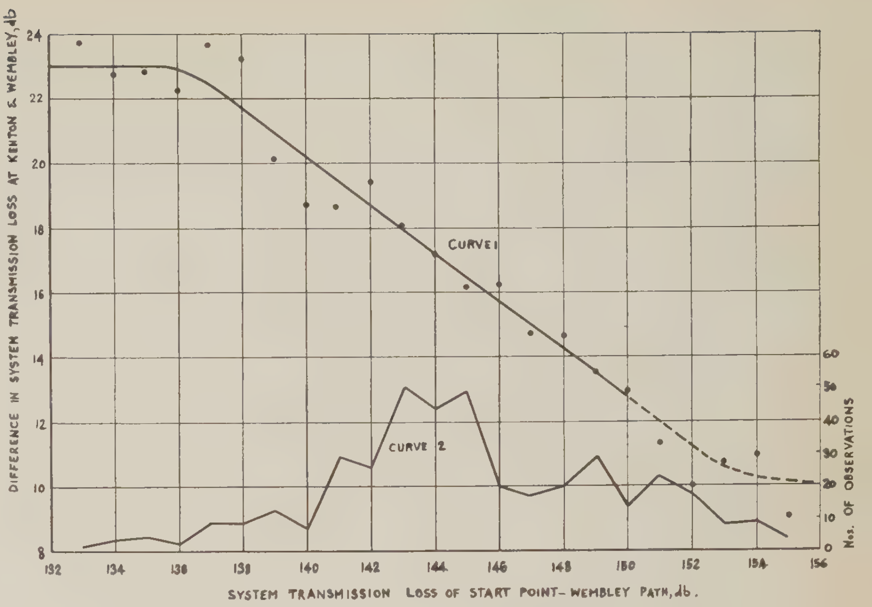

Fig. 1—Average difference in system transmission loss for Kenton and Wembley at *S* Band. Curve 1—average transmission loss difference. Curve 2—number of measurements available for averaging.

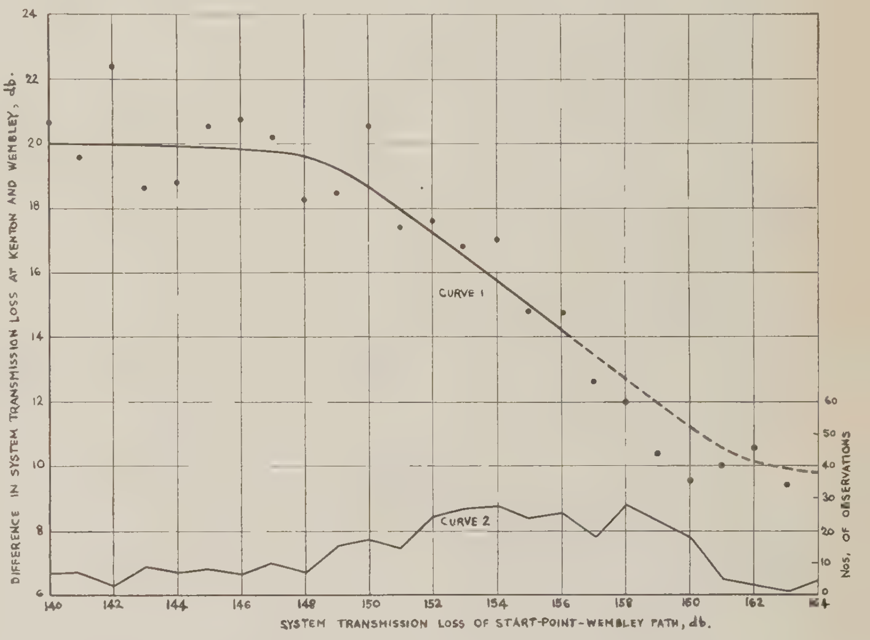

Fig. 2—Average difference in system transmission loss for Kenton and Wembley at *X* Band. Curve 1—average transmission loss difference. Curve 2—number of measurements available for averaging.

In periods when the transmission loss was high, the Kenton signal occasionally fell below the receiver noise level and the resulting loss of information undoubtedly led to an underestimate of the average difference at the higher values of *L*. The points at which the loss of information started to become significant corresponded to values of *L* of about 150 and 156 db at *S* and *X* band, respectively. It seems probable that, if full information were available, the difference curves in each case would level off to a constant value of perhaps 10 or 11 db. These results are of some practical interest. In a scatter system it is the lower excursions of the median level which are of primary importance since these determine the system reliability. In the event of being forced to accept an antenna site somewhat poorer

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* Received by the IRE, April 7, 1961.

[1] B. C. Angell, *et al.*, "Propagation measurements at 3,480 Mc/s over a 173 mile path," *Proc. IEE*, vol. 105, pt. B, suppl. no. 8, pp. 128–142; 1958.

[2] G. V. Geiger, N. D. La Frenais, and W. J. Lucas, "Propagation measurements at 3,480 and 9,640 Mc/s beyond the radio horizon," to be published in *Proc. IEE*.

[3] K. A. Norton, P. Rice, and L. E. Vogler, "The use of angular distance in estimating transmission and fading range for propagation through a turbulent atmosphere over irregular terrain," Proc. IRE, vol. 43, pp. 1488–1526; October, 1955.

than desired, the above results suggest that the actual deterioration in performance may be several db less than might be expected from the theories.

During the propagation program, the amplitude distribution of the S-band signal was examined over a large number of periods varying in duration from 5 minutes to 1 hour. In general, it was found that the distribution was similar to that of a Rayleigh vector plus a coherent component, the distributions on the whole approaching the pure Rayleigh case and, therefore, presumably the propagation approaching pure scatter, at the lower values of the median signal level. It is interesting to note that, if it is assumed that in the experiments described above, the difference between the Kenton and Wembley signals tends to a constant value of about 10 db, then the θ dependence of the received power at low levels is about θ^{-3} rather than θ^{-5} given by Norton, Rice, and Vogler.[3]

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On the Linear Circuit Aspects of Cryotrons*

In a recent paper Cohen[1] has presented an expression for the gate resistance of a cryotron in the transition region. It was assumed that the gate resistance is a linear function of the gate and control currents. His expression is of the form

$$R_g = K(ai_G + i_C - I_0). \qquad (1)$$

where R_g is the gate resistance, i_G is the gate current, i_C is the control current, and K, a, and I_0 are constants that depend upon the device configuration. Such an expression is quite adequate for many applications. However, at times it may be desirable to have a more accurate expression for the cryotron characteristic. The expression proposed here has the same form as (1) except that, in order to account somewhat for the nonlinearities present, it is raised to some power. That is

$$\begin{array}{lll} R_g = K(ai_G + i_C - I_0)^n & 0 \le K(ai_G + i_C - I_0)^n \le R_n & \\ \quad = 0 & (ai_G + i_C - I_0) < 0 & \\ \quad = R_n & K(ai_G + i_C - I_0)^n > R_n & (2) \end{array}$$

where R_n is the normal resistance of the gate.

This expression has been matched with some experimental results,[2] and they are both plotted in Fig. 1. The experimental results are indicated by the plot points. The constants used here were obtained by the usual curve-fitting techniques and are $n=2$, $K=4.7$, $a=0.92$, $R_n=10.7$ millohms and $I_0=0.056$. A better fit to the curves can be obtained by using a more elaborate expression for R_g. However, (2) does provide a fairly close fit over much of the region of interest such that more elaborate forms of (2) are required to account for the curvature near the value of normal resistance. However, this region of operation often is not important. In the following discussion it is not, so that (2) suffices here.

Eq. (2) may be used to obtain the gate current vs gate voltage characteristics, which are the output characteristics of the cryotron. The equation that represents these characteristics can be obtained from the relation $e_G = i_G R_g$, where e_G is the gate voltage. The use of this equation results in

$$\begin{array}{lll} e_G = i_G K(ai_G + i_C - I_0)^n & 0 \le K(ai_G + i_C - I_0)^n \le R_n & \\ \quad = 0 & (ai_G + i_C - I_0) < 0 & \\ \quad = i_G R_n & K(ai_G + i_C - I_0)^n > R_n. & (3) \end{array}$$

A plot of (3) is shown in Fig. 2. An inspection of the results indicates that linear operation of this device similar to that of vacuum tubes and transistors is feasible. Several troublesome features of this operation, such as the thermal hysteresis effect, require further investigation.

In a paper entitled "The Controlled Superconductor as a Linear Amplifier," which is to be published in a forthcoming issue of the IRE Transactions on Component Parts, the authors develop further the above-mentioned ideas. In addition, the authors also derive linear equivalent circuits for controlled superconductors as well as expressions for the gain and efficiencies of cryotrons under various conditions of linear operation.

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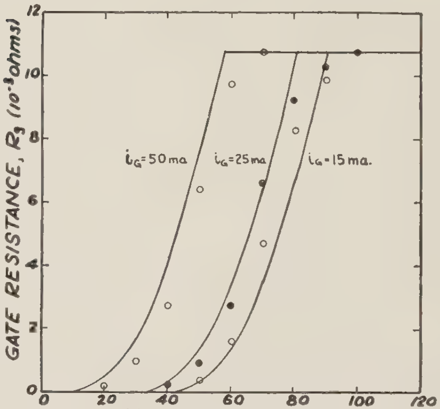

Fig. 1—Gate resistance vs control current, with gate current as a parameter.

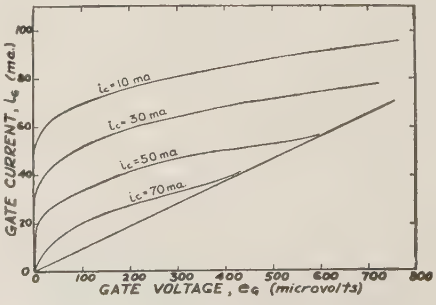

Fig. 2—Cryotron output characteristics.

* Received by the IRE, April 12, 1961.

[1] M. L. Cohen, "Thin film cryotrons—Part III," Proc. IRE, vol. 48, pp. 1576 1582; September, 1960.

[2] G. Parkins, "A Cryotron Equivalent Circuit," M.S. Thesis, Dept. of Elec. Engrg., New York University, New York, N. Y.; 1959.

A Method for Determining the Base Voltage and Contact Resistance of a Conductivity-Modulated Diode*

The transient behavior of semiconductor diodes is influenced by several parameters including junction voltage, carrier lifetime, base conductivity, and contact resistance. The time rate of decay of an impressed voltage across a diode may be observed by biasing the diode in the forward direction, suddenly opening the circuit, and observing the decay of the injected charge carriers with a cathode ray oscilloscope. Such an oscilloscope trace of the voltage decay in a p-i-n junction structure is diagrammed in Fig. 1.

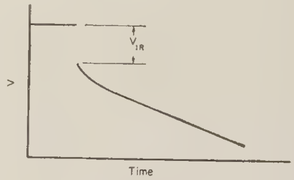

Fig. 1—Voltage decay curve.

Before the switch is opened, the voltage across the device is the sum of the junction voltages, the base voltage, and the voltage developed at the diode contacts. After the switch is opened, the base and contact voltages decay with essentially a zero time constant resulting in the initial vertical portion of the scope trace. The rest of the trace is associated with the transient currents resulting from EMF's developed at the n-i and i-p junctions due to nonequilibrium concentrations of charge carriers in the junctions. The linear portion of this part of the trace which is associated with the fundamental mode of charge carrier decay is characteristic of the charge carrier lifetime.[1,2] Preceding the linear portion of the curve,

* Received by the IRE, March 3, 1961.

[1] B. R. Gossick, "Post-injection barrier electromotive force of p-n junctions," Phys. Rev., vol. 91, pp. 1012–1013; August, 1953.

[2] S. A. Lederhandler and L. J. Giacoletto, "Measurement of minority carrier lifetime and surface effects in junction devices," Proc. IRE, vol. 43, pp. 477–483; April, 1955.

there is generally a steeper slope which may be attributed to the higher modes of decay[3] and which may not always be distinguishable from the infinite slope associated with the *IR* component of the voltage, depending on the frequencies of the higher modes and the time constant of the scope.

The contact resistance of a diode is generally deduced from the ohmic portion of the diode impedance by calculating base resistance from the material constants and subtracting from the total ohmic component. However, this is not possible in a conductivity-modulated diode since the base resistance depends on the injection level of the current carriers.

For a *p-i-n* diode operated in the conductivity-modulated state, both the conductivity of the base region and the carrier density in the base region are exponentially increasing with applied voltage at the same rate. The result is that the base voltage is relatively independent of current for these high levels of carrier injection.[4] Therefore, the dynamic change in voltage with current in the region of high-level injection is a direct measure of the contact resistance of the device. To determine this dynamic impedance in a particular silicon *p-i-n* diode with a 25-mil-wide base, the ohmic component of the voltage-time trace—that is, the quantity V_{IR} shown in Fig. 1—was measured at several current levels and plotted against the current, as shown in Fig. 2.

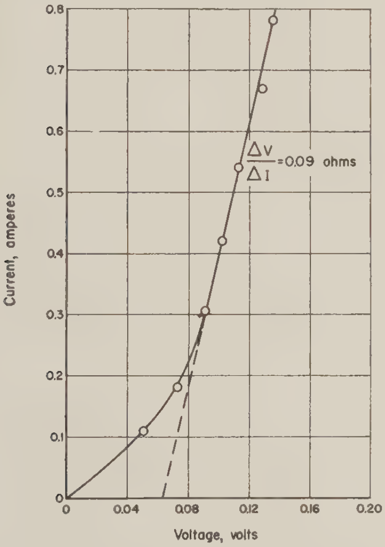

Fig. 2—"Resistive" component (V_{IR}) of voltage drop across diode vs forward current.

The higher modes of decay of the injected carriers, which may not be distinguishable on the scope trace from the *IR* component of the voltage, are assumed to have negligible amplitude. Were the amplitude of the higher modes to be appreciable, the error introduced by this assumption would affect the base voltage only, and not the contact resistance, since the contact resistance is determined from the slope of the curve, and the base voltage from the zero-current intercept.

The conductivity-modulated state of the diode, *i.e.*, constant base voltage, is shown in Fig. 2 to exist above a current load of about 0.3 ampere. The slope of the current-voltage curve in this region is determined by the contact resistance of the device, and represents a resistance of 0.09 ohm.

An extrapolation of the high-level-injection portion of the current-voltage curve to the voltage axis gives the base voltage. Assuming equal resistance at each of the two contacts, a specific contact resistance of 0.0032 ohm cm², and a constant base voltage under conditions of high-level injection of 0.064 volt were obtained.

Since the slope of the conductivity-modulated portion of the I-V_{IR} curve represents the contact resistance, decreasing the area of the contacts should result in a proportionate increase in contact resistance. Consequently, the diode was lapped to half its original area and the I-V_{IR} data were again taken. The value of contact resistance calculated from the new curve was 0.17 ohm, which is consistent with the reduction of contact area within the limits of experimental error.

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[3] D. T. Stevenson and R. J. Keyes, "Measurement of carrier lifetimes in germanium and silicon," *J. Appl. Phys.*, vol. 26, pp. 190–195; Feburary, 1955.

[4] M. B. Prince, "Diffused p-n junction silicon rectifiers," *Bell Sys. Tech. J.*, vol. 35, pp. 661–684; May, 1956.

Receivers with Zero Intermediate Frequency*

An interesting note was published in these Proceedings on the above subject.[1] A zero-IF (or homodyne) receiver is one in which output is delivered from the first detector or mixer directly at video, or zero IF, rather than at a finite intermediate frequency. The note showed that noise has been considered a major problem in the use of zero IF, and that modern mixers and oscillators have reduced this problem considerably. It is obvious that further improvement is possible by preceding the mixer by low-noise RF amplification.

An experimental zero-IF receiver was set up some years ago by Dr. Charles E. Chase, Jr., of the M.I.T. Lincoln Laboratory. With sufficient low-noise RF gain before the mixer—a poor mixer noise figure is unimportant. Such a receiving system was tried, using an RCA experimental A-1038 *S*-band low-noise traveling-wave tube as an RF amplifier. The experimental system is shown in Fig. 1. Two traveling-wave tubes were used in cascade, and the output fed into a balanced mixer with the local oscillator operated at the signal frequency. The mixer output was fed into a video amplifier with balanced input.

If the mixer in a zero-IF system is perfectly balanced, it operates as a perfect multiplier, and interfering signals farther from the stalo frequency than the video bandwidth are rejected. In practice, however, the balance between the two crystals in the balanced mixer is not perfect; consequently, the rectified components at the two crystals do not cancel out and there is detection of signals, to some extent, occurring anywhere in the input pass band.

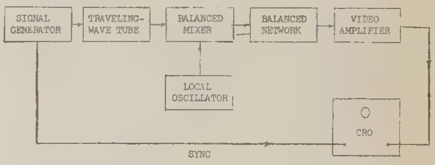

Fig. 1—Zero-IF receiver test apparatus.

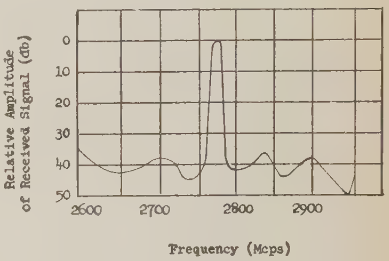

Fig. 2—Rejection of interfering signals by zero-IF receiver.

Although it is possible to balance the output of the crystals at video to cancel interfering signals by perhaps 60 db at some particular frequency, the balance is frequency dependent. Fig. 2 shows the relative amplitude of received signal as a function of frequency, for optimum balance of the above setup over a range of frequencies. The rejection is approximately 40 db, over a range of several hundred Mc, using a standard balanced mixer. For comparison, in a typical superheterodyne system (with an unbalanced mixer) it was found that the interfering signal was rejected by 90 db except at the image, where rejection was only 30 db (and this rejection was due to the TR-tube bandwidth). However, while noise-figure measurements were being made, it was observed that interference from nearby radars was considerably less with the zero-IF receiver than with a similar heterodyne IF receiver of the same over-all gain. This was probably due to the greater ease of shielding the zero-IF receiver.

With the two traveling-wave tubes, having a combined gain of about 45 db, the over-all noise figure, measured with a fluorescent-tube noise source, was 10.8 db. This is the same as the noise figure of the first tube, within experimental error (±0.2 db). Thus, the mixer noise contribution was negligible. With a single traveling-wave tube, the noise figure was 17.7 db; because of insufficient gain before the mixer, the video noise contribution of the latter was excessive.

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* Received by the IRE, March 16, 1961. The research reported in this note was supported by the Dept. of the Air Force under AF Contract No. AF 33(600)39852.

[1] J. C. Greene and J. F. Lyons, "Receivers with zero intermediate frequency," Proc. IRE, vol. 47, pp. 335–336; February, 1959.

It was believed that the relatively poor balance of the balanced mixer was caused by warping of the diaphragm. A new mixer was therefore ordered which used a heavy wedge-shaped member instead of the relatively flimsy diaphragm. Although this mixer was expected to have considerably better balance than the old one, the results were not appreciably different.

If the bandwidth preceding the traveling-wave tube were restricted by a tunable narrow-band filter, then the problem of interfering signals would be considerably reduced. It is also advisable to restrict the input bandwidth since arbitrary received signals over the wide input bandwidth of the traveling-wave tube can be expected to add rms-wise if they occur at the same time, and a total signal can be produced in the traveling-wave tube large enough to reduce seriously the effective dynamic range of the tube. Even with the super-heterodyne, it is helpful to incorporate a tunable filter before the receiver to reduce interference from other radars.

With the zero IF, one has the possibility of a simpler system configuration than with the superhererodyne. In a pulse Doppler radar, the IF strip, synchrodyne, reference oscillator, and IF coherent detector, and any of the specialized power supplies are exchanged for the traveling-wave tubes and their specialized power supplies. This exchange did not appear warranted at the time, in view of the relatively advanced state of design of the former elements. However, with further advances in the traveling-wave tube art, the zero-IF radar may prove to be simpler and easier to maintain.

With the present availability of traveling-wave tubes with noise figures as low as 3 db, the use of zero-IF receivers would be more interesting now and should receive consideration.

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A Magnetic Shield for Beam Frequency Standards*

The accuracy of the present cesium-beam atomic frequency standards is limited at least in part by the uncertainty and the inhomogeneities in the magnetic *C*-field region of the machine (see Fig. 1). This uncertainty in the magnetic field arises from two sources: 1) the inability to generate the known uniform magnetic field required to maintain spatial quantization, and 2) the inability to shield out the magnetic field generated by the earth and the environment.

At present, with mu-metal shields it is possible to reduce this uncertainty over the length of the interaction region to about ±2 milligauss, which corresponds to an uncertainty in the cesium-beam frequency standard of about four parts in 10^{12}. It should be possible to reduce the error resulting from the externally generated fields by the use of a superconducting magnetic shield. It was shown by Meissner, in 1933, that the magnetic field in a superconductor is zero, and comparatively recently, it has been shown that as long as the magnetic field is well below the critical value, a superconductor behaves as a perfect magnetic shield.[1] However, at the current state of the art, a lower limit of about 10^{-6} gauss is set by problems in making an entire closed surface superconducting.

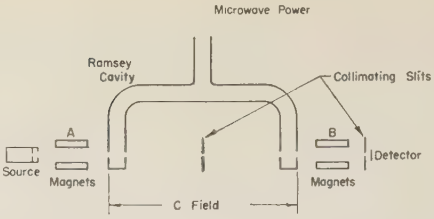

Fig. 1—Schematic of a beam frequency standard.

At present, it is not easy to estimate just how much improvement could be obtained by the use of a superconducting shield in an atomic beam machine which requires a small magnetic field to maintain space quantization of the magnetic dipole moment; however, in the case of a molecular beam machine using an electric dipole transition, it should reduce the small magnetic perturbations to a completely negligible value.

The author wishes to express his appreciation to R. Beehler and C. Snider, of the National Bureau of Standards, for providing a means for making a rough experimental check on the shielding effects of a superconductor, and to the U. S. Army Signal Corps for supporting work on the development of a molecular beam frequency standard.

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* Received by the IRE, May 1, 1961.

[1] J. Babiskin, "Magnetic properties of a hollow superconducting lead sphere," *Phys. Rev.*, vol. 85, pp. 104–106; January, 1952.

A Monopulse Instrumentation System*

In a conventional RF sum and difference amplitude-sensing monopulse direction finder, the tracking error relative to the beamwidth caused by extraneous phase shifts is (See Appendix)

$$E = \frac{\delta}{2} \sin \psi, \qquad (1)$$

where δ is the differential phase shift before the comparing hybrid and ψ is the phase shift after the comparing hybrid. (A similar expression applies to phase-sensing systems for amplitude precomparator and phase post-comparator unbalance.)

Since error and reference signals are processed in similar but not identical receivers, the differential phase shift ψ causes boresight shift or imposes unduly small limits on δ, particularly in multiple-pole, narrow-band IF amplifiers. Because of these errors, a method of instrumentation was evolved which eliminates this source of errors.

In the system shown in Fig. 1, the outputs of two elementary antennas are compared in a conventional hybrid to form difference (Δ) and reference (Σ) array outputs. The difference output, which represents a pointing error signal, is modulated and recombined with the reference output.

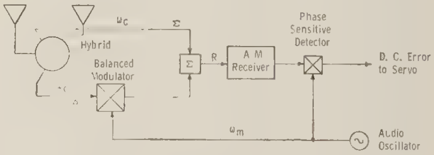

Fig. 1—Block diagram of the monopulse instrumentation system.

The resultant signal is of the form:

$$R = A(\cos \theta + \sin \theta \sin \omega_m t) \cos \omega_c t. \qquad (2)$$

For small error angles:

$$R = A(1 + \theta \sin \omega_m t) \cos \omega_c t. \qquad (3)$$

Thus, the resultant is readily seen to be amplitude modulation whose phase-sensitive amplitude is proportional to directional error. The boresight error, due to parasitic phase shift, is shown by (1).

The receiver output is an audio voltage proportional in amplitude to the error signal. This phase of audio voltage changes 180° upon crossing zero error. This voltage is readily phase compared with the local audio modulation oscillator to provide a dc output for the servo.

Signal processing devices may be very broad-band without affecting system sensitivity and, hence, may be made to produce little or no random phase shift. The critical narrow-band IF amplifier is eliminated as a cause of errors, since reference and error signals undergo the same phase shift in it.

Systems of this type have been built in the laboratory and have exhibited identical results with the usual monopulse system but without sensitivity to phase shifts in the narrow-band amplifiers. Such systems are easy to align and are stable under extremes of environment.

Appendix

Derivation of (1) is as follows:

$$A(\theta, t) = \sin (k + \theta) \cos w_c t$$

where k = offset angle, θ = error angle.

$$B(\theta, t) = \sin (k - \theta) \cos (\omega_c t + \delta)$$
$$= \sin (k - \theta)(\cos \delta + j \sin \delta) \cos \omega_c t.$$

* Received by the IRE, April 17, 1961.

Here, $A(\theta, t)$ and $B(\theta, t)$ are the amplitude responses of the antenna elements.

$$\Delta = A - B = [\sin(\theta + k) - \cos\delta \sin(k - \theta) - j \sin\delta \sin(k - \theta)] \cos \omega_c t$$

$$= 2\left[\sin^2\left(\frac{\delta}{2}\right) \sin k \cos\theta + 2\cos^2\left(\frac{\delta}{2}\right) \sin\theta \cos k - j \sin\delta \sin(k - \theta)\right] \cos\omega_c t.$$

$$\sum = A + B$$

$$= \left[-2\sin^2\left(\frac{\delta}{2}\right) \sin\theta \cos k + 2\cos^2\left(\frac{\delta}{2}\right) \sin\theta \sin k + j \sin\delta \sin(k - \theta)\right] \cos\omega_c t.$$

For many applications, $k=45°$ (*i.e.*, crossover is at the half-power point) and $\sin k = \cos k = \sqrt{2}/2$. Further near the null, $\theta \ll 1$ and $\delta \ll 1$, hence,

$$\sin\theta \overset{\circ}{=} \theta, \qquad \cos\theta \overset{\circ}{=} 1,$$

$$\sin(k - \theta) \overset{\circ}{=} \sqrt{2}/2$$

and $\sin\delta \overset{\circ}{=} \delta$, $\cos\delta \overset{\circ}{=} 1$.

With these approximations,

$$\Delta = \sqrt{2}\left[\left(\frac{\delta}{2}\right)^2 + \theta - j\frac{\delta}{2}\right] \cos\omega_c t$$

$$\overset{\circ}{=} \sqrt{2}\left(\theta - j\frac{\delta}{2}\right) \cos\omega_c t.$$

$$\sum = \sqrt{2}\left[-\left(\frac{\delta}{2}\right)^2 \theta + 1 + j\frac{\delta}{2}\right] \cos\omega_c t$$

$$\overset{\circ}{=} \sqrt{2} \cos\omega_c t.$$

If Δ is phase detected with respect to Σ, after a phase shift of ψ,

$$\Delta_{dc} = \sqrt{2}\,\theta \cos\psi - \frac{\delta}{2} \sin\psi.$$

Thus, the output voltage Δ_{dc} is reduced by the factor $\cos\psi$ (which is usually negligible), and an extra error $\delta/2 \sin\psi$ is added.

ACKNOWLEDGMENT

Much credit is due G. Kruesi whose work and ideas on low-frequency direction finders have contributed substantially to the system shown above. Credit is also due C. Sordal whose analysis of the system has contributed to the understanding of error effects.

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A Traveling-Wave Maser Using Chromium-Doped Rutile*

An X-band traveling-wave maser amplifier which differs in two respects from previously[1,2] reported traveling wave masers has been operated. 1) It is the first time to our knowledge that chromium-doped rutile[3] has been used as the paramagnetic material for traveling-wave masers. 2) Appreciable gain-per-unit length with a very large tunable bandwidth has been obtained without the use of any external slowing structure.

The structure that was employed is shown in Fig. 1. Standard size X-band waveguide is used with dielectric tapers leading to and from the active material. The cross-sectional dimensions of the active material are 0.074 inch by 0.150 inch leading to a cutoff frequency of 3 kMc. The small cross section is used because of the large dielectric constant of rutile, 131 for E field perpendicular, and 256 for the E field parallel to the C axis at 4.2°K. The pump frequency is coupled to the system through a Y section and is coupled to the active material by the same dielectric tapers used for the signal frequency. The pass band of the structure is thus limited only by how well one can match into a waveguide filled with a material of high dielectric constant.

Amplification was observed at different frequency intervals from 8 to 10 kMc. At certain frequencies, due to reflections at the dielectric tapers and junctions, cavity Q's between 100 and 1000 were observed. The amplifier at these frequencies exhibited the larger gains and narrower bandwidths which are indicative of cavity operation. The large reflections, and hence the cavities, can be eliminated by known matching procedures.

Some of the characteristics of the amplifier operating at a signal frequency of 8.44 kMc with a 35.85-kMc pump frequency in a magnetic field of 4.4 kilograms are shown in Fig. 2. The gain of 2.4 or 3.8 db with a bandwidth of 20 Mc is for an active material length of 0.75 inch and a rutile-chromium content of 0.07 per cent. This corresponds to a gain of 5 db per inch at 4.2°K. The measured gain at 1.4°K was 6 db or 8 db per inch. These values compare favorably with the calculated values of 3.2 db at 4.2°K and 9.6 db per inch at 1.4°K. The calculated values were based on a slowing factor $S=15$, $N=0.54$ (where N is the number of free-space wavelengths) and magnetic Q's of -90 and -30 at 4.2 and 1.4°K, respectively. It should be noted that this maser was operated using only one ion per unit cell.[3] An amplifier can make use of the two ions per unit cell and thereby increase the gain in db per inch by a factor of two.

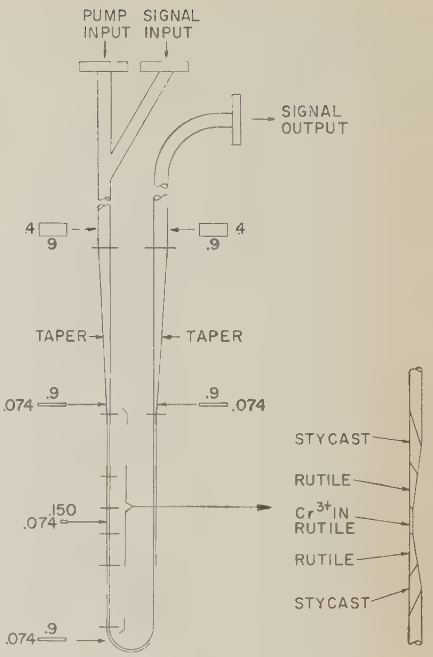

Fig. 1—A traveling-wave maser with no external slowing structure.

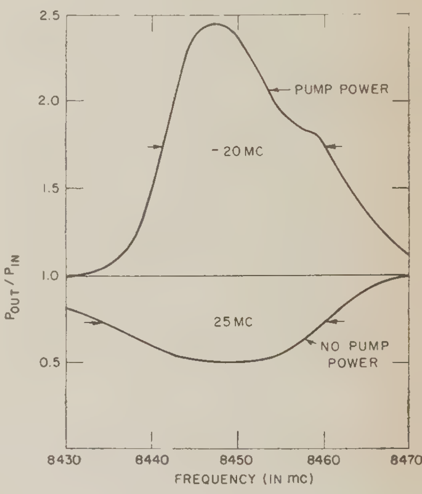

Fig. 2—Normalized power curve for the traveling-wave maser with and without pump power.

The inversion ratio which is defined as the ratio of transmitted power with saturating pump power to transmitted power without pump power both expressed in decibels, was -1.24 and -0.6 at 4.2 and 1.4°K, respectively. By assuming equal relaxation times, the theoretical value of the inversion ratio is -1.13. The experimental value compares favorably at 4.2°K but is surprisingly low at 1.4°K and is probably due to cross relaxation effects.

Fifty milliwatts of pump power was required for saturation. At a signal power output of 30 μw or -15 dbm, the gain of the amplifier is reduced to one half the maximum value. This value of 30 μw can be compared with the 6 μw observed for a ruby traveling-wave maser at Bell Laboratory.[1] The power level at which the amplifier saturates is in agreement with a spin-lattice relaxation time of a few msec. Previous results using pulse techniques gave 2.4 msec.

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* Received by the IRE, April 19, 1961. This work is partially supported by the U. S. Army Signal Corps, under Contract No. DA 36-039-SC-87386.

[1] R. W. DeGrasse, E. O. Schulz-du Bois, and H. E. Scovil, "The three-level solid state traveling wave maser," *Bell Sys. Tech. J.*, vol. 38, pp. 305–334; March, 1959.

[2] W. S. C. Chang, J. Cromack, and A. E. Siegman, "Cavity and traveling-wave masers using ruby at *S*-band," 1959 IRE WESCON CONVENTION RECORD, pt. 1, pp. 142–151.

[3] H. J. Gerritsen, S. E. Harrison, and H. R. Lewis, "Chromium-doped titania as a maser material," *J. Appl. Phys.*, vol. 31, pp. 1566–1571; September, 1960.

In an attempt to increase the inversion ratio, the pump frequency was increased to 70 kMc. However, because of insufficient power the pump transition could not be saturated and only small gains for X-band signal frequencies were observed at 1.4°K. Gains of 3 db were observed in the 22–24 kMc range with the same structure.

This amplifier using chromium-doped rutile as the paramagnetic material should be a useful device in future systems because of its very large tunable bandwidth and simple structure. To realize this potential, isolation should be incorporated in the structure.

The authors wish to acknowledge the help of M. Heller for assistance in constructing the equipment, and H. Lewis, for his helpful technical discussions.

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Shaping of Distributed RC Networks*

In the study of integrated single crystal and evaporated film circuits, attempts to make adequate inductance have met with only limited success. Therefore it becomes necessary to pay more attention to the possible uses of resistance and capacitance. In "solid" circuitry, resistance and capacitance will generally occur in distributed form, so that new properties may appear which are not realizable in conventional lumped circuitry. Distributed RC networks have been discussed in previous literature.[1–4] The form which has been generally considered is illustrated in Fig. 1 and may be represented by the circuit element of Fig. 2. Johnson[4] analyzed the straight distributed network, for the particular application of vacuum-tube phase-shift oscillators, and set up a design theory taking the grid capacitance into account. In this context only the voltage transfer characteristic was of interest. The analysis showed that with the use of untapered distributed networks, voltage attenuation factors as low as 8 should be realized at the frequency for phase reversal, and it was also concluded that in the limit of steep tapering the attenuation should approach unity. These results indicate a considerable improvement over the more conventional untapered 3-section RC phase-shift network, for which the open-circuit voltage-attenuation factor is 29 at the frequency for a 180° phase shift.

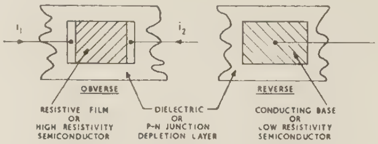
i_1
i_2
OBVERSE
REVERSE
RESISTIVE FILM OR HIGH RESISTIVITY SEMICONDUCTOR
DIELECTRIC OR P-N JUNCTION DEPLETION LAYER
CONDUCTING BASE OR LOW RESISTIVITY SEMICONDUCTOR

Fig. 1—Linear-distributed RC network.

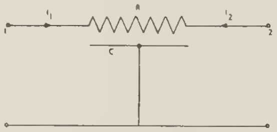

Fig. 2—Circuit representation of distributed network.

In "solid" and evaporated film circuits, the active network elements will be transistors and, in this case, it is appropriate to consider current transfer functions with network loads of the order of 1000 ohms. An investigation of shaped networks is being carried out, with initial emphasis on the realization of current phase reversals with small attenuation. The network was treated as a tapered transmission line, and solutions were obtained in closed form for the case of exponential shaping, in which the RC product per unit length is invariant with position along the line. Thus, with the origin of X at the input 1 of the network, we have

$$R(x) = R_0 e^{mx} \quad \text{ohms/unit length,}$$
$$C(x) = C_0 e^{-mx} \quad \text{farads/unit length.}$$

Solution of the line equations for such a network leads to the following Z-parameters:

$$Z_{11} = \frac{R_0}{2\alpha^2 \sinh \frac{\gamma L}{2}} \cdot \left(m \sinh \frac{\gamma L}{2} + \gamma \cosh \frac{\gamma L}{2} \right)$$

$$Z_{12} = \frac{R_0 \gamma e^{mL/2}}{2\alpha^2 \sinh \frac{\gamma L}{2}} = Z_{21}$$

$$Z_{22} = \frac{R_0 e^{mL}}{2\alpha^2 \sinh \frac{\gamma L}{2}} \cdot \left(\gamma \cosh \frac{\gamma L}{2} - m \sinh \frac{\gamma L}{2} \right),$$

where

$$\gamma = \sqrt{m^2 + 4j\omega R_0 C_0},$$

$$\alpha^2 = j\omega R_0 C_0,$$

R_0, C_0 and m are previously defined,

$$\omega = 2\pi \times \text{frequency},$$

$$L = \text{network length}.$$

Writing

$$R_0 C_0 = T_0 = \frac{1}{\omega_0},$$

we may then use

$$\omega R_0 C_0 = \frac{\omega}{\omega_0} = U$$

as a relative frequency parameter. The curve of Fig. 3 was calculated from the relation

$$T_N = \frac{Z_{12}}{Z_{22} + Z_L}.$$

where T_N is the current transfer function for the particular values,

$$m = -5,$$
$$L = 1 \text{ cm},$$
$$R_0 = 10^5 \text{ ohms/cm},$$
$$\text{load} = Z_L = 500 \text{ ohms}.$$

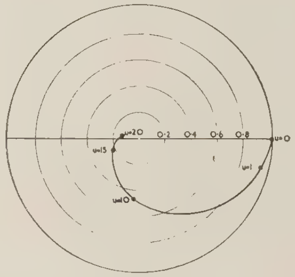

Fig. 3—Polar plot of current transfer function of a distributed RC network. $m=-5$, $L=1$ cm, $R_0=10^5$ ohms/cm, and $Z_L=500$ ohms.

From this curve, it may be seen that for 180° phase change, $U \doteq 18$ and the current is attenuated by a factor of about 6, *i.e.*, 16 db. Further trial calculations indicated that this was much better than could be obtained with a "straight" network. However the expression for T_N is too complicated to be easily optimized by analytical means.

Several 10-section lumped component analogs have been built, and current and voltage attenuations were measured at the frequency for phase reversal. The theoretical calculations for the above example were first checked, and the agreement was fairly good in that phase reversal occurred at $U \doteq 20$ with a current attenuation factor of 7. Further measurements indicated the existence of an optimum m-value depending on the R_0/Z_L ratio. Measurements on open-circuit voltage transfer provided direct comparison with a straight distributed network and the normal 3-section RC phase-shift network. The network with $m=+5$ gave an attenuation factor of 4.5, while the "straight" distributed network and the 3-section network give attenuation factors of 12 and 29, respectively. It is apparent that shaped distributed networks can offer considerable improvement over the more conventional forms. By using the lumped analog to provide feedback from collector to base of a common-emitter transistor amplifier, it was possible to obtain oscillations up to 500 kc. Furthermore, the particular component values used in the feedback circuit were of

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* Received by the IRE, April 14, 1961.

[1] C. K. Hager, "Network design of microcircuits," *Electronics*, vol. 32, pp. 44–49; September, 1959.

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the same order as the maximum values which may be realized in the practical distributed networks used in micro-circuitry. With suitable design, it should be possible to obtain oscillations well into the megacycle range.

In order to gain a fuller understanding of the characteristics of the shaped networks, the voltage and current transfer functions together with the input and output impedances are being computed for a variety of shapes and loads, and the results so obtained will be reported elsewhere. It should then be possible to set up a design procedure for optimum use of the networks. The experimental data obtained so far indicate new ways of designing "solid" oscillators and selective amplifiers, and it is hoped to do this using a wafer of silicon with distributed capacitance provided by a reverse-bias p-n junction. The advantage of using depletion layer capacitance, rather than an evaporated dielectric system, lies in the possibility of tuning by means of the junction bias voltage, and also in the fact that the low dielectric loss is maintained up to very high frequencies.

ACKNOWLEDGMENT

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Proposed Technique For Modulation of Coherent Light*

A technique for the modulation of the coherent-light output of a ruby laser has been proposed[1] at the Millimeter Wave Research Laboratory, Purdue University, Lafayette, Ind. This technique makes use of the Stark effect in the ruby itself. By applying a strong electric field to the ruby, the energy levels involved in the laser action can be shifted, with the shift dependent upon the strength of the applied field. This results in a frequency shift of the coherent-light output. If the applied field is a strong microwave signal, then the resultant output will be frequency modulated.

The required field strength of a reasonable frequency deviation is difficult to calculate, but may be determined experimentally. An estimate of the order of magnitude of the required field may be obtained from a consideration of the Stark shift of an isolated hydrogen atom. Von Hippel[2] gives the equation for the frequency as

$$\nu_e = \frac{3\epsilon_0 h}{2\pi m e} nE \approx 1.93 \times 10^4 \, nE$$

where

ϵ_0 = permittivity of free space
h = Plank's constant
m = electronic mass
e = electronic charge
n = principal quantum number
E = field strength in v/m.

For the chromium ions in ruby, $n=3$, and hence,

$$\nu_e \approx 5.29 \times 10^4 E.$$

For a field strength of 10^5 v/m, a frequency shift of

$$\nu_e \approx 5.29 \times 10^9$$

or 0.18 cm^{-1} is obtained. This is a large enough frequency deviation to be observed with a good interferometer. Higher field strengths will, of course, result in larger deviations.

A problem which arises is the pump efficiency. In order to obtain the required high field strengths at microwave frequencies, the ruby will have to be placed in a waveguide or a microwave cavity. Thus sufficient light will have to be focussed on the ruby from a source external to the cavity. Since, at present, rather high energy is required from the pump source, difficulties may be encountered in achieving laser action in configuration.

The frequency modulated light may be converted to amplitude modulated light by passing it through a Fabry-Perot etalon which will act as a band-pass filter. The output of the etalon may then be detected by a photosensitive envelope detector.

The relaxation oscillations which have been observed in ruby lasers may make any form of modulation difficult. However, it is assumed that the problem of achieving constant output over the pulse period can be solved.

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* Received by the IRE, June 15, 1961.

[1] Application for patent, "Frequency modulation of coherent light," submitted to Purdue Res. Found.; March, 1961.

[2] A. Von Hippel, "Dielectrics and Waves," John Wiley & Sons, Inc., New York, N. Y.; 1954.

A Generalization of "Mutual Information"*

As usually defined, "mutual information" relates to two random variables, say x and y; their mutual information $I(x:y)$ is the amount of information that one random variable gives about the other, *i.e.*, the information x and y have in common. It can be expressed as

$$I(x:y) = H(x) - H(x \mid y) \tag{1}$$

in terms of the entropy and conditional entropy (equivocation) of x. With the help of Fig. 1, we can find the mutual information of three random variables, *i.e.*, the amount of information common to, say, x, y, and z:

$$\begin{aligned} I(x:y:z) &= I(x:z) - I(x:z \mid y) \\ &= I(y:z) - I(y:z \mid x) \\ &= I(x:y) - I(x:y \mid z), \end{aligned} \tag{2}$$

in which the last term, for example, is the average conditional value of (1). The last line of (2) says that the information z has in common with both x and y is that part of the information common to x and y which is not independent of z; this relation bears a close resemblance to (1). Eq. (2) can also be written in the symmetric form

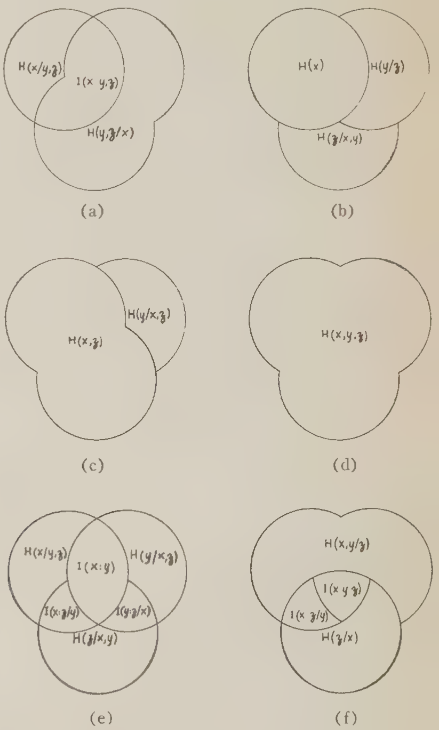
$$\begin{aligned} I(x:y:z) = H(x) + H(y) + H(z) - H(y, z) \\ - H(x, z) - H(x, y) + H(x, y, z) \end{aligned} \tag{3}$$

which is reminiscent of the familiar $I(x:y) = H(x)+H(y)-H(x, y)$.

The mutual information of n random variables $x_1, \cdots, x_n$ similarly turns out to be

$$\begin{aligned} I(x_1: \cdots :x_n) = I(x_1: \cdots :x_{n-1}) \\ - I(x_1: \cdots :x_{n-1} \mid x_n), \end{aligned} \tag{4}$$

which can be expressed in a symmetric form, like (3), as the sum of all entropies of a single variable minus the sum of the entropies of all pairs plus the sum of the entropies of all triples, etc. With the aid of Fig. 1, we can also show that $H(x_1, \cdots, x_n)$ is the sum of all entropies of a single variable minus the sum of the mutual informations of all pairs plus the sum of the mutual informations of all triples, etc.



(a) (b) (c) (d) (e) (f)

Fig. 1—Relationships among the entropies and mutual informations of x, y, and z. The designation of the central triangle as $I(x:y:z)$ can be justified by noting, for example, that $I(x:y, z) = I(x:y) + I(x:z) - I(x:y:z)$.

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* Received by the IRE, April 26, 1961.

Note added in proof: It has just come to the author's attention that this generalization, though presented somewhat differently, appears in Fano[1] and McGill.[2] The present exposition, however, may help to clarify the idea.

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[1] R. M. Faro, "The Transmission of Information," Massachusetts Institute of Technology Press, Cambridge, and John Wiley and Sons, Inc., New York, N. Y., sec. 2.12, pp. 57–59; 1961.

[2] W. J. McGill, "Multivariate information transmission," IRE Trans. on Information Theory, vol. IT-4, pp. 93–111; September, 1954.

"A Broad-Band Termination for IF Coaxial Lines"*

Referring to Stull's note,[1] we would like to inform you that a similar problem has been approached and solved in a different manner at CERN, Geneva, Switzerland.

In connection with the construction of an electron accelerator, the question arose concerning feeding a cavity resonator through a nearly lossless transmission line (Fig. 1).

Starting from the transfer impedance function

$$Z_T = \frac{V_2}{I_1} = \frac{Z_0 Z_r}{Z_0 \cos \frac{s}{j\omega_0} \frac{\pi}{2} + jZ_r \sin \frac{s}{j\omega_0} \frac{\pi}{2}}, \quad (1)$$

with

$$Z_r = \frac{\omega_0 \sqrt{L/C}\, s}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}, \quad (2)$$

and developing the sine and cosine functions into an infinite product, it is possible to find easy expressions for sine and cosine functions in the neighborhood of $s \cong j\omega_0$ (ω_0 being the resonant frequency of the quarter wavelength line and of the resonator). Then

$$\begin{cases} \cos \frac{s}{j\omega_0} \frac{\pi}{2} \cong \frac{\pi}{4\omega_0^2}(s^2 + \omega_0^2) \\ \sin \frac{s}{j\omega_0} \frac{\pi}{2} \cong 1. \end{cases} \quad (3)$$

Introducing (3) into (1) and solving Z_T by means of the root-locus method, we find Z_T to be characterized by 4 poles p_A, p_B, p_A^*, p_B^* in the vicinity of $j\omega_0$. The actual position of these poles is a function of what we call the coupling factor k:

$$k = \sqrt{\frac{\sqrt{L/C}}{Z_0}}. \quad (4)$$

By increasing k, the coupled poles p_A, p_B, p_A^*, p_B^* move along the lines drawn in Fig. 2.

Magnifying the region around $j\omega_0$, it can be shown that p_A, p_B poles lie on a circle centered in p_L with radius

$$\Omega = \omega_0 \sqrt{\frac{\sqrt{L/C}}{\pi Z_0}}, \quad (5)$$

at a distance $\omega_0/4Q$ from the j axis (Fig. 3).

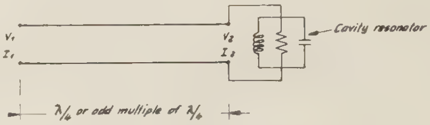

Fig. 1.

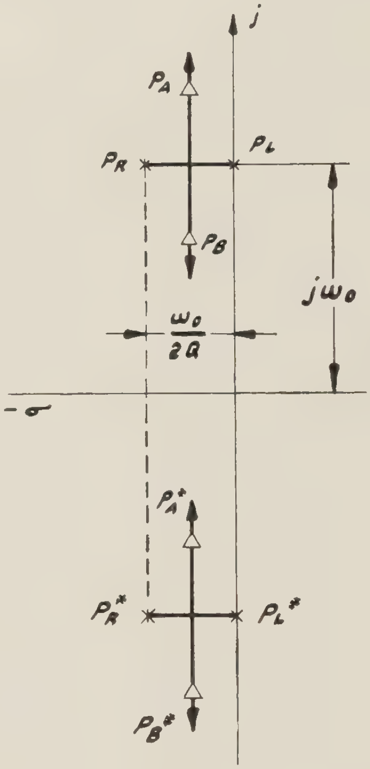

Fig. 2.

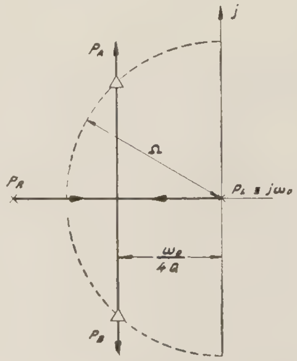

Fig. 3.

If we now feed the line from a constant current source, we find on the resonator either a flat or a double-peaked frequency response, depending on the factor k.

Good agreement with (5) has been observed in practice for bandwidths up to 40 per cent.[2]

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* Received by the IRE, April 6, 1961.

[1] K. S. Stull, "A broad-band termination for IF coaxial lines," Proc. IRE, vol. 49, pp. 365–366; January, 1961.

[2] F. A. Ferger and A. Susini, "Wide Band Impedance Matching by the Root-Locus Method. Application to the Design of a High Power Radio-Frequency System for an FFAG Accelerator," CERN Rept. No. 60-41; October, 1960.

Tracking and Display of Earth Satellites*

There are several errors in the above titled article.[1] A list of the typographical errors follows:

(2) for y should read:

$$y = a\sqrt{1 - e^2} \sin E$$

(8) for C should read:

$$C = e\sqrt{(k_3)^2 + (k_1)^2}.$$

The line immediately following (15) should read:

> " . . . for $e \leq 0.1$, produces errors not greater than 1 . . . . "

Slack and Sandberg derived equations for a satellite subtrack. They considered the special case for a circular orbit to reduce the equations to a presentable form. I disagree with their method of reduction. I also question several points in their derivation.

In the first step in the derivation, the equations of motion for a set of axes whose x member coincides with the semimajor axis of the satellite's elliptic path are transformed to a new set of axes in the same orbital plane whose x member passes through the point of maximum latitude. This is a rotation through an angle called β. The statement is then made that since $\omega = 90° - \beta$, this transformation can be written in terms of ω, the argument of the perigee. I fail to see why the point of maximum latitude was used since the transformation in terms of ω can be performed directly. It actually may be more convenient to make this transformation through the angle ω rather than $90° - \omega$. In this case, the x member of the new set of axes would pass through the ascending node.

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* Received by the IRE, February 14, 1961.

[1] F. F. Slack and A. A. Sandberg, "Tracking and display of earth satellites," Proc. IRE, vol. 48, pp. 655–663; April, 1960.

In the third transformation, the equations of motion (referred to a set of axes fixed in space and with the x and y members in the equatorial plane) are fixed to a rotating earth by rotation through the angle $\gamma+\omega_e t$. The authors neglected defining γ. Obviously it is the angle from x'' to x''' at time $t=0$, *but* no $t=0$ is defined. Since the expression for the eccentric anomaly is written in terms of $t-T_p$, the transformation must be through the angle $\gamma+\omega_e(t-T_p)$. Now, when $t=T_p$, γ is the angle from x'' (fixed in space) to x''' (the reference axis in the equatorial plane—presumably Greenwich). The use of $t-T_p$ leads to changes in (13), (14), (16), (17) and (21).

Besides the typographical error in (8) for C, there are three other errors in these equations. The following are the correct expressions for ϕ, α, and p:

$$\phi = -\gamma - \tan^{-1}\frac{(k_3+k_2)}{(k_1+k_4)}$$

$$\alpha = -\gamma - \tan^{-1}\frac{(k_4+k_1)}{-(k_2+k_3)}$$

$$\rho = \gamma - \tan^{-1}\frac{k_1}{k_3}\,.$$

It will be noted that some simplification of the equations given by the authors is possible. Specifically:

$$A = D \qquad \delta = \theta + 90°$$

$$B = F \qquad \alpha = \phi - 90°$$

$$C = G \qquad \rho = \psi + 90°.$$

The authors considered a special case as an example. A circular orbit ($e=0$) was chosen and then it was assumed that $\omega=0$, $T_p=0$, and $\gamma=0$. However, when a circular orbit is assumed, ω and T_p no longer have any meaning. This indeterminancy can be eliminated if the constants are evaluated before any assumptions are made. One would expect that the magnitude constants (A, B, C and H) are independant of ω as e approaches zero. It is easily shown, neglecting higher-order terms in e, that:

$$A = a\sin^2\left(\frac{i}{2}\right)$$

$$B = a\cos^2\left(\frac{i}{2}\right)$$

$$C = ea\sqrt{1-\sin^2 i\sin^2\omega}$$

$$H = a\sin i$$

$$\theta = \gamma + \omega - 90°$$

$$\phi = -\gamma + \omega - 90°$$

$$\psi = \gamma - 90° - \tan^{-1}(\cos i\tan\omega)$$

$$\tau = \omega - 90°.$$

Hence, to a first-order approximation, A, B, and H are functions of the semi-major axis and the inclination of the orbit only. If a circular orbit is assumed, $C=0$ regardless of the value of ω. The authors have implied that it is necessary to assume $\omega=0$ to evaluate these constants for the special case. Actually, no assumptions are necessary to evaluate these constants for even the general case.

In order to get a simple illustrative example, one can certainly assume, quite arbitrarily, that the perigee is at the ascending node (therefore $\omega=0$). There is no need to assume $T_p=0$ since all the equations are now in terms of $t-T_p$. We can again, quite arbitrarily, assume a value for γ. The authors have chosen to use 0° which fixes the reference axis to the longitude where the point of maximum latitude occurs.

When one assumes that $\omega=0$ and $\gamma=0$, the phase angles have the following values: $\theta=-90°$, $\phi=-90°$, $\delta=0$, $\tau=-90°$, $\alpha=-180°$, $\psi=-90°$, $\rho=0$. The last three are incorrectly given in the article.

It is only necessary to calculate two of the subtrack equations given by the authors since a spherical earth has been assumed. (This is a valid assumption since only a 1 per cent accuracy is desired.) Instead of calculating the subtrack in cartesian coordinates, one can just as easily calculate the subtrack in spherical coordinates: λ and Ω, where Ω is measured from x'''.

$$\lambda = \sin^{-1}\frac{Z_{ss}}{R}$$

$$\Omega = \cos^{-1}\frac{X_{ss}}{R\cos\lambda}\,.$$

The error corresponding to a 1 per cent accuracy in the cartesian subtrack equation would be about one-half degree.

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High-Level Microwave Detector Using Avalanche Injection*

A semiconductor diode has been built which has interesting properties as a large-signal microwave detector. At 9350 Mc, rectified voltages up to 12 v across 200 Ω have been obtained with input power ranging from 1 to 3 w. In addition, at somewhat lower input power, some of these diodes have delivered more rectified power than was available from the microwave source. Crude measurements at very low levels indicate that these diodes are not useful for small-signal applications. This may be because of the large noise associated with breakdown.

The avalanche-injection microwave (AIM) diode was constructed by placing the point of a tungsten whisker in the bottom of an etchpit in a silicon die of 0.2-ohm-cm resistivity. An ohmic contact was provided by lightly alloying from a thin, vacuum deposited layer of Au-O.6 per cent Sb before plating with nickel for soldering. This assembly was installed in a 1N23 package. The thickness of the silicon between the bottom of the etchpit and the ohmic contact was 10 μ and the radius of the tungsten point was approximately 2 μ.

Microwave rectification is poor when the point is biased negative with respect to the semiconductor (back direction) and for this reason the back characteristic is not presented here. The I-V characteristic of a typical diode in the forward direction as taken from an oscilloscope trace is shown in Fig. 1. Gunn's[1] treatment of rectification and avalanche at a current constriction leads to a static characteristic closely resembling Fig. 1 below the breakdown current. According to his theory, the nearly flat part of the characteristic just below breakdown is due to the onset of drift velocity saturation. The saturation current density is given by $J_0=qN_dV_{ds}$, where q is the electronic charge, N_d is the donor density, and V_{ds} is the saturation drift velocity. Gunn gives an experimental value of 8.5×10^6 cm/sec for V_{ds}. Using this value along with our value of 2.5×10^{16}/cm^3 for N_d, a value of 34×10^3 amperes is obtained for J_0. If we assume that the current just below breakdown in Fig 1. is $J_0\,A$, where A, the contact area, is about 10^{-6} cm^2, a value of 35×10^3 amperes is obtained for J_0.

The entire negative-resistance region can be understood qualitatively in terms of the avalanche-injection theory of Gunn[1] which postulates that minority carriers from the avalanche are injected into the drift region. Gunn[1] and Gibson and Morgan[2] have developed a quantitative theory for the low-voltage branch of the negative-resistance region which is in agreement with our data.

Rectification measurements were made on commercially available microwave rectifier diodes as well as on AIM diodes using a pulsed microwave source and an oscilloscopic display. The commercial diodes deliver only about 3 v or 40 mw to a 200-ohm load, presumably because of their poor back characteristics, while about half of the AIM diodes delivered 10 v or ½ w to the same

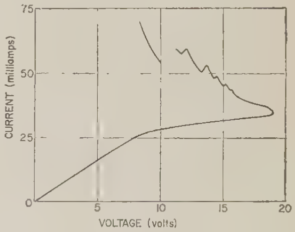

Fig. 1—Static characteristics of the avalanche-injection microwave diode.

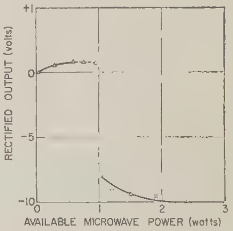

Fig. 2—Rectification characteristics of the avalanche-injection microwave diode at 9350 Mc with the bias at 16 v and the video load at 200 Ω.

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* Received by the IRE, May 1, 1961.

[1] J. B. Gunn, "High electric field effects in semiconductors," *Progress in Semiconductors*, vol. 2, pp. 213–247; 1957.

[2] A. F. Gibson and J. R. Morgan, "Avalanche injection diodes," *Solid State Electronics*, vol. 1, pp. 54–69; March, 1960.

load, and an occasional diode has delivered 12 v or 0.7 w.

For the AIM diodes, the dependence of rectified power on available microwave power for fixed tuning and bias depends strongly on the bias. The data plotted in Fig. 2 were obtained at a bias about 3 v below the breakdown voltage. Note that the rectified voltage undergoes a change of polarity at the discontinuity. There is a range of power input, in this case from about 1 to 3 w, in which the output is nearly independent of the input. Just below this, the curve is broken to indicate uncertainty in the measurements due to distortion of the pulse shape as observed on the oscilloscope. A small fraction of the AIM diodes showed power gain as mentioned above. In this case tuning and bias were critical and the power input was in the 30- to 50-mw range. This effect is undoubtedly related to the negative resistance, and of course, the sum of the bias power and the input microwave power exceeds the rectified power.

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Coherent Generation of Microwave Power by Annihilation Radiation of a Prebunched Beam*

Coherent electromagnetic power at the 100-mw level has been produced in the millimeter region by the creation and annihilation radiation of a tightly bunched 0.8-Mev electron beam. The creation-radiation process, as in beta emission, results from the sudden creation of a charge moving at a constant velocity. The annihilation-radiation process, on the other hand, is similar to the radiation associated with the two-quanta annihilation process in quantum theory.[1]

In the experiments performed, a prebunched beam enters the structure through a small hole and travels a distance of several wavelengths before impinging on a flat conducting surface, as shown schematically in Fig. 1. The resulting radiation is transmitted through a coaxial horn and then into detection and measuring devices.

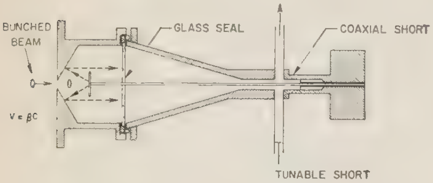

Fig. 1—Schematic of assembly used with a metal target (tellurium copper).

The performance of the device is based on the following considerations: Assume that an infinitely long beam is incident normal to the surface of a conducting material. If the conducting surface is infinite in extent, its effect on the electromagnetic fields can be adequately accounted for by replacing the surface with an image beam traveling in the opposite direction to the electron beam. The resulting power radiated per unit solid angle is

$$P(\Omega) = \sum_n \frac{\eta_0 I_n^2}{8\pi^2} \frac{\beta^2 \sin^2 \theta}{(1 - \beta^2 \cos^2 \theta)^2}, \qquad (1)$$

where $\eta_0 = 120\pi$ is the free-space impedance, I_n is the beam-harmonic current, $\beta = v/c$ is the ratio of beam velocity to the velocity of light, θ is the angle between the direction of motion of the beam and the point of observation, and finally the summation in (1) extends over the harmonics of the beam.

To find the total power radiated, (1) is integrated over the solid angle. Due to the special geometry used, the power expression must be integrated over 4π steradians. The resulting power in terms of the radiation resistance is

$$P = \sum_n \tfrac{1}{2} I_n^2 R_n, \qquad (2)$$

where R_n, the radiation resistance, is given by

$$R_n = \frac{\eta_0}{2\pi}\left[\frac{1+\beta^2}{2\beta} \ln\left(\frac{1+\beta}{1-\beta}\right) - 1\right]. \qquad (3)$$

Thus, for a 0.8-Mev beam, the radiation resistance is 140 ohms. Furthermore, the radiation resistance is independent of frequency, a fact of paramount importance with regard to operation in the submillimeter region.

Experimentally the radiation resistance was measured in the frequency range 30–40 kMc. The results are shown in Fig. 2, wherein the radiation resistance exhibits a seemingly random variation with frequency. This is partly due to the presence of a vacuum glass seal which introduces a dispersive element into the system. In addition, the beam length is comparable to a wavelength.

The fact that the beam is of finite length, and that it enters the structure through a hole whose size is small compared to a wavelength, introduces a new element into the problem. It can be shown that for the above conditions the total power radiated is about twice that calculated for the case of simple beam annihilation.[2] The added power comes from beam-creation radiation at the entrance hole. Thus the total radiation resistance for a 0.8-Mev beam is of the order of 280 ohms and takes into account both creation and annihilation radiation.

Effects of beam scattering at the target surface have been largely neglected. However, there is experimental evidence which indicates that the intense localized heating at the point of impact affects the power level.

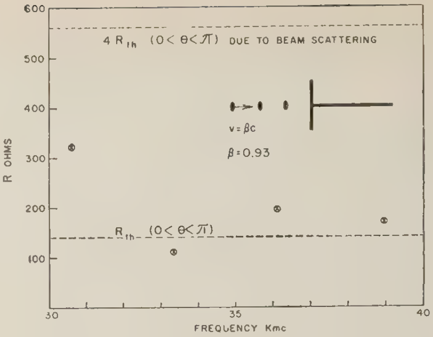

Fig. 2—Radiation resistance as a function of frequency.

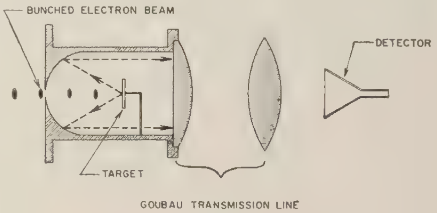

Fig. 3—Proposed optical-electronics method of generating coherent electromagnetic power by creation-annihilation radiation.

For wavelengths below two millimeters, conventional waveguides become lossy. Also mode interference problems preclude the use of such waveguides below one millimeter. In this region optical techniques become useful and the creation-annihilation scheme is ideally suited for such applications. A schematic of a proposed optical creation-annihilation device is shown in Fig. 3. The dimensions of the device are several orders of magnitude larger than a wavelength. An optical-type Goubau transmission line is used to transmit the power to the detector.

Finally, coherence conditions require that the bunch size be smaller than a wavelength. However, the creation-annihilation radiation phenomenon depends to a large extent on the nature of the beam at two points in space, namely the point where the beam enters the structure and the point where it is annihilated.[3] Therefore, the bunches do not have to retain their tightness over a long distance of interaction as in Cerenkov and other devices. Hence the coherence requirement on the beam is that its bunches be pointwise tight. This obviates the problems involved in preserving the bunches over long distances, and hence lower-energy beams can be used. This improves the over-all efficiency of the system. Also, since the radiation resistance is expected to remain invarient with frequency, the power yield in the submillimeter region should be appreciable.

In conclusion, the authors wish to thank Prof. P. D. Coleman for his support and interest in the problem, and for making available the Rebatron on which the above-mentioned experiments were conducted.

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* Received by the IRE, June 19, 1961.

[1] W. Heitler, "The Quantum Theory of Radiation," Oxford University Press, London, Eng., 1953.

[2] B. W. Hakki and H. J. Krumme, "Coherent Generation of Annihilation Radiation by a Tightly Bunched Megavolt Electron Beam," presented at Conf. on Electron Device Research, Troy, N. Y.; June, 1961.

[3] G. A. Askar'yan, "Pulsed coherent generation of millimeter radiowaves by non-relativistic electron bunches," *Soviet Phys. JETP* (Letter), vol. 3, pp. 613–614; November, 1956.

WWV and WWVH Standard Frequency and Time Transmissions*

The frequencies of the National Bureau of Standards radio stations WWV and WWVH are kept in agreement with respect to each other and have been maintained as constant as possible with respect to an improved United States Frequency Standard (USFS) since December 1, 1957.

The nominal broadcast frequencies should for the purpose of highly accurate scientific measurements, or of establishing high uniformity among frequencies, or for removing unavoidable variations in the broadcast frequencies, be corrected to the value of the USFS, as indicated in the table below. The corrections reported have been arrived at by means of improved measurement methods based on LF and VLF transmissions.

The characteristics of the USFS, and its relation to time scales such as ET and UT2, have been described in a previous issue,[1] to which the reader is referred for a complete discussion.

The WWV and WWVH time signals are also kept in agreement with each other. Also they are locked to the nominal frequency of the transmissions and consequently may depart continuously from UT2. Corrections are determined and published by the U. S. Naval Observatory. The broadcast signals are maintained in close agreement with UT2 by properly offsetting the broadcast frequency from the USFS at the beginning of each year when necessary. This new system was commenced on January 1, 1960. A retardation time adjustment of 20 msec was made on December 16, 1959; another retardation adjustment of 5 msec was made at 0000 UT on January 1, 1961.

WWV FREQUENCY WITH RESPECT TO U. S. FREQUENCY STANDARD

1961 May	Parts in 10^{10}†
1	−150.5
2	−150.3
3	−149.7
4	−149.4
5	−149.6
6	−149.8
7	−149.9
8	−149.9
9	−149.9
10	−149.8
11	−149.9
12	−150.0
13	−150.3
14	−150.6
15	−150.3
16	−150.2
17	−150.1
18	−150.0
19	−149.6
20	−149.8
21	−149.8
22	−149.6
23	−149.5
24	−149.7
25	−149.6
26	−149.3
27	−149.6
28	−149.7
29	−149.6
30‡	−149.8
31	−150.6

† A minus sign indicates that the broadcast frequency was low. The uncertainty associated with these values is $\pm 5 \times 10^{-11}$.

‡ Frequency adjusted -1×10^{-10} on May 30 at 1900 UT.

NATIONAL BUREAU OF STANDARDS
Boulder, Colo.

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* Received by the IRE, June 26, 1961.

[1] Refer to "National Standards of Time and Frequency in the United States," Proc. IRE, vol. 48, pp. 105–106; January, 1960.

Self-Educating Machines for Recognition and Classification of Patterns*

The direct reading of characters (letters or numbers) by a machine has found many applications. It is rather easy to do when the characters are taken from a given well-restricted set. This leads, for instance, to the automatic recognition of account numbers on bank checks. When the machine is asked, on the other hand, to recognize letters as well as the trained human eye does, the problem becomes a very complex one. It has been suggested, with some success, that a machine which would have the possibility of classifying a great number of input patterns into a small number of output classes should not be worked out to its final details at the designing stage and, in particular, should not rigidly provide automatically a classification of the patterns chosen *a priori*. Indeed, when the number of input patterns becomes very large the implementation of a given classification at the drawing-board level may become quite unwieldy. One may hope for a machine which can train itself just like the human eye does, provided it is possible to tell the machine when its classification is in error. Such machines are made of an array of input sensing elements, which transform the input pattern laid on them into an input signal in a one to one correspondence with the pattern. This input signal is transformed into an output which is in a one to one correspondence with the classification desired. The output is not only used as an output; it is also fed back into a memory device where the desired correspondence between the input patterns and the output classification has been stored. If the comparison with the memory is satisfactory, the machine is ready for the next input pattern. If it is not satisfactory, the machine transforms certain of its inner parameters (values of certain circuit elements) in such a way that the incorrect result will become less probable when, in the future, the same input pattern shall occur.

The first point one must make is that the memory device mentioned does indeed contain the drawing-board classification which was deemed unwieldy. The only advantage gained is that, possibly, the classification in the memory can be changed at will. This, indeed, provides a very large versatility. One may visualize a machine, for instance, which classifies aerial photographs in certain classes. The classification desired may depend then on the intended use of the photographs at a given time.

The machines in existence today, to my knowledge, have however a very important drawback. Not all possible classifications can be learned and some classifications, while learnable, may necessitate a great number of self-adjustments (a great number of pattern trials) before they are learned. Indeed, most of the literature on the subject is on the mathematics of the restrictions involved and one may wonder why the authors of such articles are so delighted with the shortcomings of their own proposals. Such shortcomings are not inherent to the problem and it is rather easy to propose machines which do not have any. All that is necessary, for instance, is for the input signal, in a one to one correspondence with the input pattern, to move a magnetic memory tape. The motion of the tape will place a location of the tape under an output reading head which is in a one to one correspondence with the input signal. The output reading will be fed back to the memory device described before and compared with the desired output. If this output is not proper, the location on the tape just read will be moved by the machine to a location under an erasing and printing head where the desired output will be printed on the tape. In this manner, any possible classification can be learned and can be learned within the smallest number of trials (equal to the number of different input patterns used). In practice, the memory device could be the tape itself thus eliminating all but the sensing raster, the mechanism moving the tape, and the output reading head. A library of tapes would provide the versatility, and duplication (by just duplicating such tapes) would be quite easy.

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* Received by the IRE, April 25, 1961.

On Parametric Amplification in Transistors*

A mode of parametric amplification using transistors was proposed by Vodicka and Zuleeg,[1,2] who reported on a converter circuit which they say provides very high gain by a combination of mixing and parametric amplification. Their basic circuit, without bias connections, is shown in Fig. 1. The circuit was reconstructed in this laboratory and the gain reported by Vodicka and Zuleeg was reproduced. However, we did not find the reported stability. Also, we differ on some of the theoretical considerations presented.

The principle of operation of the circuit is as follows: The oscillating transistor provides the pump frequency, and its emitter the nonlinear impedance, for parametric amplification of an incoming signal. Therefore, the power level of the difference frequency at the input terminals may be higher than that of the input signal. If this difference frequency is much smaller than the cutoff frequency of the transistor, additional gain is available from the transistor at the output terminals.

The circuit is apparently a two-frequency oscillator. Redrawing Fig. 1 for high frequencies as Fig. 2, we can immediately see

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* Received by the IRE, March 21, 1961.

[1] V. W. Vodicka and R. Zuleeg, "Transistor operation beyond cut-off frequency," *Electronics*, vol. 56, pp. 56–60; August, 1960.

[2] R. Zuleeg and V. W. Vodicka, "Parametric amplification properties in transistors," PROC. IRE (Correspondence), vol. 48, pp. 1785–1786; October, 1960.

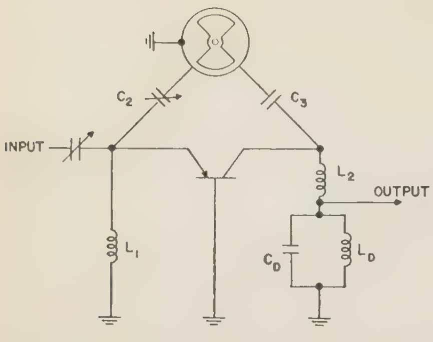

Fig. 1—The ac portion of the circuit proposed by V. W. Vodicka and R. Zuleeg.

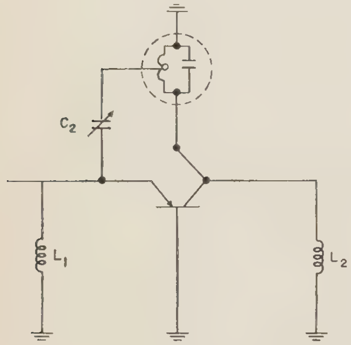

Fig. 2—The high-frequency oscillator.

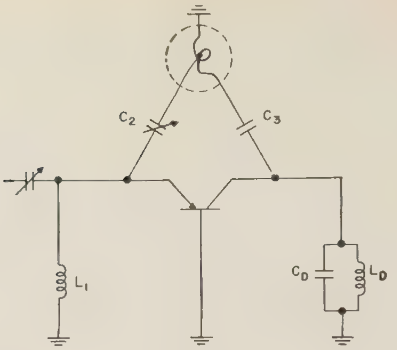

Fig. 3—The basic circuit for low frequencies. C_2 adjusts the feedback for both high and low frequencies and is very important for low frequencies.

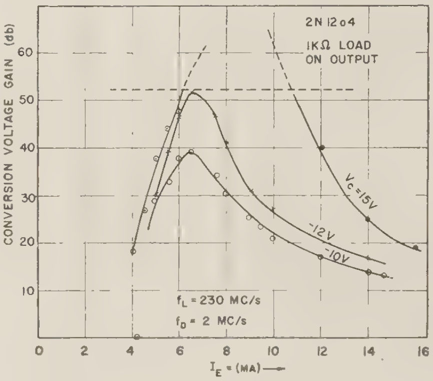

Fig. 4—Conversion gain as a function of emitter current, with collector voltage as a parameter, for a 2N1204 micro-alloy diffused-base transistor. With the 1$k\Omega$ load in the circuit, oscillation occurs at f_D above 52-db voltage gain.

that the circuit is a Hartley oscillator which will oscillate at a frequency determined by the butterfly, as pointed out by the authors. For low frequencies, Fig. 3 is the equivalent circuit. This is the case for a difference frequency of a few megacycles. As is apparent from Fig. 3, the circuit can also oscillate at a low frequency mostly determined by L_DC_D. However, due to the small amount of feedback at the difference frequency f_D, conditions are not very favorable for low-frequency oscillation.

Favorable conditions at the butterfly frequency allow oscillation to occur at f_L, beginning at fairly low bias currents. Due to the unfavorable conditions at low frequencies, oscillation will occur for f_D only over a fairly narrow current range, *i.e.*, in the neighborhood of maximum power gain.[3] The circuit components are such that unity loop gain at f_D can be obtained only near the power gain maximum.

If the current and collector voltage are set such that the loop gain is not quite sufficient for low-frequency oscillation, a narrow-band high-gain amplifier for f_D is the result. (The transistor is, of course, oscillating meanwhile at f_L.)

The circuit mixes an input signal at the frequency f_S with f_L to result in a signal at the difference frequency f_D, which is then amplified by the high-gain amplifier. It is apparent that the greater part of the high gain results *not* from parametric amplification but from the narrow-band low-frequency amplifier. This amplifier is operating far below the transistor's cutoff frequency, and, as the low-frequency oscillatory conditions are approached, the gain becomes extremely large.

According to the above arguments, the maximum gain need not necessarily occur at the point where the input impedance becomes real, as was suggested by Vodicka and Zuleeg.[1] We have found that the input impedance of a 2N1204 micro-alloy diffused transistor is real for $I_E \approx 0.5$ ma. However, the maximum gain occurs at $I_E \approx 7$ ma, which coincides with the maximum in power gain.

Since the high gain is mostly achieved by use of a narrow-band amplifier, the stability is mainly controlled by the properties of the amplifier. As can be seen from Fig. 4, a high gain is extremely dependent upon both voltage and current. If a compromise is made to lower gain, the stability is improved accordingly.

Use of harmonic mixing (in order to extend the frequency limit) results in a worse gain stability for two reasons. First, the difference frequency easily drifts out of the narrow band of the low-frequency amplifier. Second, due to the lower pump power at the harmonics of f_L, reasonable gain is obtained only on the brink of low-frequency oscillation, when the third or fourth harmonic is used.

Summarizing the characteristics of the proposed circuit, we can say that it acts as an oscillator, mixer, and low-frequency amplifier. The resulting gain is mainly due to the narrow-band low-frequency amplifier rather than to parametric amplification.

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Author's Comment[4]

Our brief letter was not meant to furnish all the answers for the circuit's operation, but rather to point out the possibilities of parametric operation of drift transistors, which have useful, inherent, nonlinear reactances of capacitive and inductive nature. We are grateful for the measurements reported which substantiate the performance of the circuit in general. It is felt that one of the preferred modes of the circuit operation does indeed consist of parametric variation of the input capacitance of the transistor to produce down-conversion (mixing) with little or no conversion loss. The necessary pumping frequency (local oscillator) is here supplied by the transistor itself through the butterfly to the emitter. The additional gain required is supplied by the transistor itself.

Since the specific transistors used in this circuit, and their characteristics, *e.g.*, very low base-resistance, high drift field, small emitter capacitance, are of utmost significance, we would like to point out certain properties of the devices investigated in conjunction with the circuit.

Although the oscillator circuit can be identified as a Hartley type, there is an important deviation in the form of an inductance placed between emitter and base terminals. By proper choice of this L for a certain transistor, a broad-band tuning will occur. Fig. 5(a) is the normal V_{eb}-I_e characteristic of a transistor under dc bias. Fig. 5(b) is the $V_{eb}I_e$ characteristic outside of this band, and Fig. 5(c) is the same characteristic at the center of this tuning range with constant RF power from a separate local oscillator. Diode mixing with this type of characteristic has been discussed in the literature.[5] The conditions under which the characteristics exist in the tuned range [Fig. 5(c)] are:

1) Presence of nonlinear resistance and capacitance.
2) Presence of RF-power at the fundamental or the higher harmonic.

The expected electrical performance would be:

1) Down-conversion or mixing with low-conversion losses when the conductance approaches zero and possibly with conversion gain, if very low or slightly negative IF-conductance can be achieved.
2) Greatly reduced noise figures.

We are still investigating several other closely related modes in the transistor, the most important of which is the transit time and the negative impedance occurring in the circuit.

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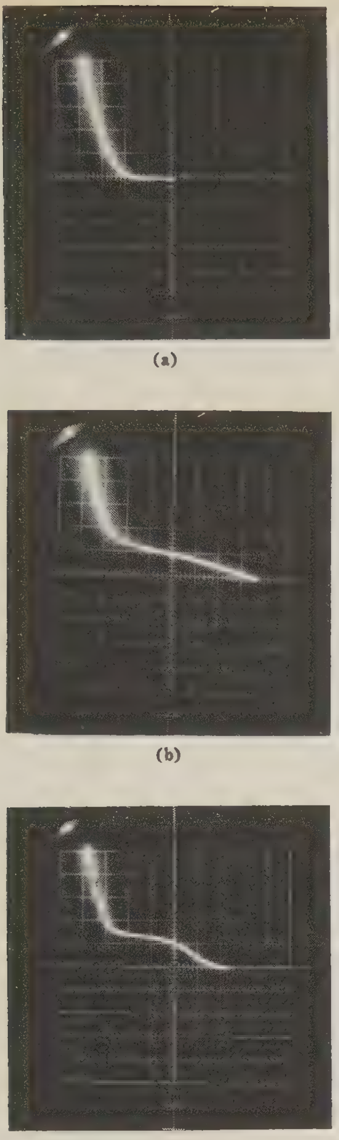
[3] As is well known, the power gain varies with the current and has a maximum for drift transistors. The magnitude of the power gain maximum increases with increasing collector voltage.

[4] Received by the IRE, May 1, 1961.

[5] R. V. Pound, "Microwave Mixers," McGraw-Hill Book Co., Inc., New York, N. Y., p. 92; 1948.



(a)

(b)

(c)

Fig. 5—*P-N-P* Hughes experimental transistor No. 314–41. (a) DC emitter-to-base characteristic with no RF power applied. (b) DC emitter-to-base characteristic with RF power at 240 Mc. (c) DC emitter-to-base characteristic with RF power at 360 Mc. Scales: Vertical—I_e in 2 ma per division. Horizontal—V_{eb} in 0.1 volt per division.

The circuits, as used, exhibited a low stability in the region of 200 Mc but became stable at frequencies above 400 Mc. For example, operation at 500 Mc produced a shift of 2000 cycles in 24 hours and approximately 2-db variation at 40-db conversion gain. The possibility of the circuit operating as a two-frequency oscillator is not excluded and can occur at certain settings. This would not necessarily explain the high gain, as the feedback, via the emitter capacitor which represents approximately 8000 ohms reactance at 2 Mc, would be facing the inductor L_1 which has a reactance of $\frac{1}{2}$ an ohm at 2 Mc.

We have found that maximum gains and the best stability are in the lower current region between $1\frac{1}{2}$ and $2\frac{1}{2}$ ma where the best noise figure is also available. The maximum bandwidth achieved up to now was approximately 1 per cent at 500 Mc.

We hope that within the near future we will be able to present a definite answer as to the transistor action in this mode of operation.

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Multiple Burst Detection*

Peterson and Brown[1] have demonstrated the potency of cyclic codes when used for error detection. In particular, they have proven that a cyclic code capable of correcting a single burst of length b bits in a block of n bits can be used to detect two bursts of b bits in the same block.

Telephonic data transmission tests have shown that bursts of errors are not distributed according to Poisson's law. The bursts themselves tend to occur in clusters. Multiple bursts of errors within a block occur much more often than would be the case with a Poisson distribution.

There exists a class of cyclic codes which can correct any t bursts of maximum length b in a block of $(2^k-1)\,b$ bits. The number of check digits required is no greater than bkt. From the work of Peterson and Brown, this code can alternatively be used to detect any $2t$ bursts of length b in a block of length $(2^k-1)b$. The following theorem provides the basis for this assertion.

If $P(x)$ is such that the cyclic code, whose feedback shift register (FSR) has $P(x)$ as its characteristic polynomial, is capable of correcting any element of the set S of error polynomials in a block of n bits, then the cyclic code whose FSR has $P(x^b)$ as its characteristic polynomial is capable of correcting any error polynomial in a block of bn bits of the form

$$\sum_{i=0}^{b-1} x^i e_i(x^b) \tag{1}$$

where $e_i(x)$ represents any element of S.

The theorem can be proven by considering two different error polynomials in the class of (1) and demonstrating that division by $P(x^b)$ yields different remainders.

For two such polynomials $E(x)$ and $E'(x)$ we can write

$$\begin{aligned} E(x) &= \sum_{i=0}^{b-1} x^i e_i(x^b) \\ &= P(x^b) \sum_{i=0}^{b-1} x^i q_i(x^b) + \sum_{i=0}^{b-1} x^i r_i(x^b) \end{aligned}$$

$$\begin{aligned} E'(x) &= \sum_{i=0}^{b-1} x^i e_i'(x^b) \\ &= P(x^b) \sum_{i=0}^{b-1} x^i q_i'(x^b) + \sum_{i=0}^{b-1} x^i r_i'(x^b). \end{aligned} \tag{2}$$

Since (2) must hold term by term:

$$\begin{aligned} e_i(x^b) &= P(x^b)q_i(x^b) + r_i(x^b), \\ e_i'(x^b) &= P(x^b)q_i'(x^b) + r_i'(x^b), \end{aligned} \tag{3}$$

for any i.

But $r_i(x^b) = r_i'(x^b)$ implies $e_i(x^b) = e_i'(x^b)$ since all $e_i(x)$ and $e_i'(x)$ have been selected from S.

It follows that

$$\sum_{i=0}^{b-1} x^i r_i(x^b) = \sum_{i=0}^{b-1} x^i r_i'(x^b)$$

implies $E(x) = E'(x)$, and this completes the proof of the theorem.

Now, if a Bose-Chaudhuri[2] polynomial $P_{BC}(x)$ is used, we can correct any t errors in a block of 2^k-1 bits with no more than kt check bits. From the theorem, it follows that, with $P_{BC}(x^b)$, we can correct any t bursts of maximum length b bits in a block of $b(2^k-1)$ bits. The number of check bits is at most bkt. There are other patterns which can be corrected by $P_{BC}(x^b)$, and if it is used solely for correcting the t bursts its efficiency is low for practical values of k, b, and t, The value of a $P_{BC}(x^b)$ code is principally in its qualities as an error detector because the decoder needed for error correction is too complex for most practical purposes. As an error detector, the $P_{BC}(x^b)$ code can detect any $2t$ bursts of maximum length b in a block of length $(2^k-1)\,b$ bits. The number of check digits required is at most bkt. There is no minimum "guard space" required between the bursts.

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* Received by the IRE, April 3, 1961; revised manuscript received, May 1, 1961.

[1] W. W. Peterson and D. T. Brown, "Cyclic codes for error detection," Proc. IRE, vol. 49, pp. 228–235; January, 1961.

[2] R. C. Bose and D. K. Ray-Chaudhuri, "A class of error-correcting binary group codes," *Information and Control*, vol. 3, pp. 68–79; March, 1960.

An Analytical Expression for Describing the Write Process in Magnetic Recording*

This note describes analytically the writing process, including self-demagnetization, in magnetic recording on a thin magnetic material. The expression developed enables one to determine the magnetization in the recording medium after writing, in relation to the geometry of the recording head, the variation of the gap field strength with time, and the hysteresis of the magnetic medium. It avoids the use of any linearization process and such terms as trapezoid magnetization function, transition length, etc.

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* Received by the IRE, May 9, 1961.

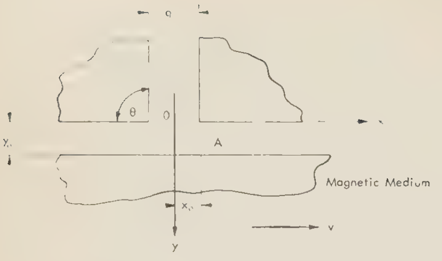

Fig. 1—Typical magnetic-recording system.

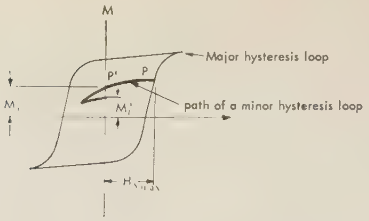

Fig. 2—Typical magnetization behavior.

Fig. 1 shows a typical magnetic recording head. In longitudinal recording (such as in a magnetic-tape, disk, or drum) one is concerned only with the x component of the field, H_x. For $\theta=\pi/2$ and at a distance y_0 from the head, H_x has been shown to be[1]

$$H_x = -\frac{H_0(t)}{\pi}\left\{\tan^{-1}\left[\frac{1+\dfrac{2x}{g_1}}{\dfrac{2y_0}{g_1}}\right] + \tan^{-1}\left[\frac{1-\dfrac{2x}{g_1}}{\dfrac{2y_0}{g_1}}\right]\right\}, \qquad (1)$$

assuming the gap field strength $H_0(t)$ is a known function of time t.

Consider any point on the magnetic material, say point A in Fig. 1. At $t=0$, point A is located at x_0; at time t, the point has moved to

$$x = x_0 + vt, \qquad (2)$$

where v is the surface velocity of the material directly below the recording head. Substituting (2) into (1), we have

$$H_x = \frac{H_0(t)}{\pi}\left\{\tan^{-1}\left[\frac{1+\dfrac{2(x_0+vt)}{g_1}}{\dfrac{2y_0}{g_1}}\right] + \tan^{-1}\left[\frac{1-\dfrac{2(x_0+vt)}{g_1}}{\dfrac{2y_0}{g_1}}\right]\right\}. \qquad (3)$$

At some time t, point A will experience some maximum field $H_{x_{\max}}$ which determines the maximum magnetization for point A. This maximum, of course, is the point at which

$$\frac{\partial H_x}{\partial t} = 0 \quad \text{and} \quad \frac{\partial^2 H_x}{\partial t^2} < 0.$$

Substituting this value of t into (3), the value of $H_{x_{\max}}$ locates point P on the hysteresis loop, as shown in Fig. 2.

When the material is moved away from the head, the magnetization at point A decreases, as described by the material's minor hysteresis loop, and reaches, at point P' (Fig. 2), a value of M_r corresponding to zero energizing field. The final value of M_r' will be somewhat less than this due to self-demagnetization—a process well described by Bayer.[2]

This procedure can be extended to other points in the material and a complete description of the magnetization in the tape can thus be obtained after the writing process.

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[1] O. Karlqvist, "Calculation of the magnetic field in the ferromagnetic layer of a magnetic drum," *Stockholm Tek. Hogskolans-Handlingar*, no. 86, pp. 1–28; 1954.

[2] R. G. Bayer, "A Theoretical Model for Self-Demagnetization," submitted for publication in *J. Appl. Phys.*

A Potential Microwave Computer Element*

In recent years there has been a search for some means of performing logic and computing operations at speeds reaching the microwave range using other than pulse operation. This communication is concerned with a bistable oscillator frequency script system of the form proposed by Edson,[1] but employing a tunnel diode as the active element.

One form of bistable oscillator, Fig. 1, consists of the connection in series of two parallel-tuned circuits and a nonlinear negative conductance. In this circuit, free oscillation can occur at either of the frequencies f_1 or f_2 associated with the two tuned circuits. Due to the nonlinearity, simultaneous oscillation at f_1 and f_2 cannot occur. The circuit, therefore, is bistable and the frequency of oscillation indicates its state. Switching between states is effected by the injection of a sufficient number of cycles of current large enough in amplitude and sufficiently close in frequency to the frequency to which the circuit is to be switched.

Fig. 2 shows a bistable oscillator which is more suited to high-frequency operation. The bistable oscillator consists of a doubly resonant, quarter-wave trough line with the tunnel diode connected across the ends of the two inner conductors. Advantages of the device are its relatively small size, simplicity, low cost, low power consumption, and relative freedom from shielding problems. An experimental model demonstrates stable oscillation frequencies of 250 Mc and 375 Mc. Experiments established that the device could be switched from one frequency state to the other, but no measurements of switching speed have yet been made. To obtain some idea of the switching speed to be expected, measurements were made with an oscillator of the form in Fig. 1 having resonant frequencies of 600 kc and 735 kc. The results are illustrated in Fig. 3. Assuming that the curve for certainty of switching lies close to that for a switching probability of 0.9, a time of the order of 10 cycles of switching frequency is necessary to effect switching when the oscillator is forced by a signal one-tenth the unloaded output amplitude of an

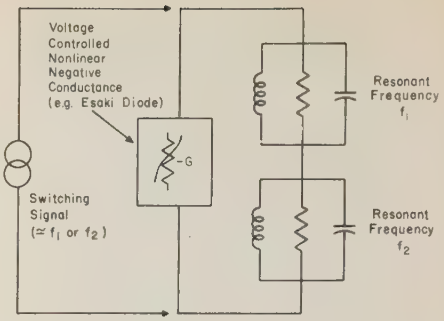
Voltage Controlled Nonlinear Negative Conductance (e.g. Esaki Diode)
-G
Switching Signal ($\approx f_1$ or f_2)
Resonant Frequency f_1
Resonant Frequency f_2

Fig. 1—Equivalent circuit of negative-conductance bistable oscillator, indicating method of switching.

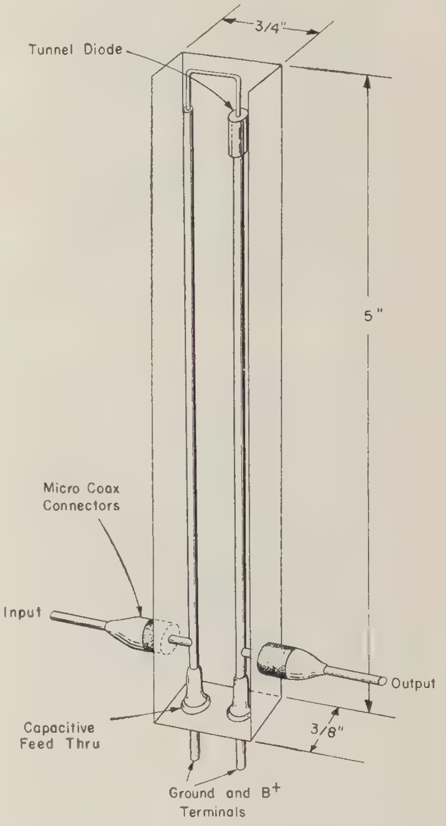

Fig. 2—The trough-line bistable oscillator.

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* Received by the IRE, April 17, 1961; revised manuscript received, May 2, 1961.

[1] W. A. Edson, "Frequency memory in multi-mode oscillators," IRE Trans. on Circuit Theory, vol. CT-2, pp. 58–66; March, 1955.

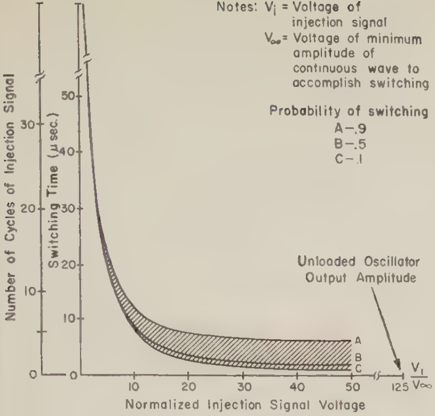

Fig. 3—Illustration of switching uncertainty.

identical oscillator. The results suggest that a useful fan-out ratio can be obtained with a switching time of about 10 cycles of switching frequency.

Bistable oscillator logic operation can be based on the majority principle. That is, if m equal amplitude, in-phase, inputs of frequency f_1 and n equal amplitude, in-phase, inputs of frequency f_2 are simultaneously applied to the bistable oscillator as switching signals, the final frequency of the oscillator is f_1 or f_2 depending on whether m or n, respectively, is the greater integer. Both AND and OR logic circuits are realized by injecting two input signals and a continuous frequency bias signal, which are all of the same amplitude, into a bistable oscillator. If the bias frequency is f_1, an output of frequency f_2 is obtained from the oscillator only when both inputs are of frequency f_2 (AND circuit); if the bias frequency is f_2, an output of frequency f_2 is obtained when either of the inputs is of frequency f_2 (OR circuit). In the COMPLEMENTATION logic circuit (output of f_2 for input of f_1, and vice versa), the single input signal is applied via a phase-reversing transformer to the bistable oscillator together with two continuous frequency bias signals, one of each of the frequencies f_1 and f_2. Due to the phase shift, concellation between the input and the bias signal of the same frequency occurs, and the output frequency is then determined by the other bias signal. Satisfactory operation of these three logic circuits is obtained only if all inputs, including frequency biases, are of nearly equal amplitude and, when of the same frequency, of essentially the same phase. The bistable oscillator is a bilateral device, but unidirectional transmission of information has been accomplished by using Goto's[2] three-beat clock bias principle. With the bistable oscillator, suitably-phased square-wave bias is applied to each tunnel diode, causing unidirectional flow to occur in a network of logic elements.

Assuming that 10 cycles of switching frequency is the order of time necessary to change the state of the bistable oscillator, it follows that to obtain a switching time of 1 nsec a bistable oscillator with characteristic frequencies of the order of ten kMc would be required.

Advantages of the bistable oscillator are: its regenerative property, coupled with its nonlinearity, results in a self-contained unit with an essentially constant output amplitude; logic can be performed with short switching times and a useful fan-out ratio; and the availability of simple high-frequency constructional techniques and extremely small tunnel-diodes offer small size, low power, and low cost. These advantages make the bistable oscillator a potentially useful microwave logic element.

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[2] E. Goto, "The parametron, a digital computing element which utilizes parametric oscillation," Proc. IRE, vol. 47, pp. 1304–1316; August, 1959.

A Solution to the Shannon Switching Game*

In a recent paper[1] a description is given of a resistor version of the Shannon switching game. A graphical version is as follows. Two players designated "cut" and "short" are presented with a finite unoriented-branch linear graph in which two of the vertices are distinguished. The cut player, in his turn, deletes one of the branches of the graph, his object being to sever all paths between the two distinguished vertices. The short player alternates moves with the cut player. In his turn he makes an unplayed branch invulnerable to deletion, his object being to connect the two distinguished vertices by an invulnerable path. Both players have complete information. The game proceeds until one of the players reaches his goal.

It can be shown by an involved argument in matroids[2] that the short player can win against all possible strategies of the cut player (the cut player playing first) if and only if the graph contains two disjoint cospanning[3] trees connecting the distinguished pair of vertices. The short player can win using a strategy of "repairing" any play (deletion) of the cut player on one tree by a play on the remaining tree. The play in general is not unique, and the strategy need not win in a minimum number of plays. It has one remarkable feature. There exist two disjoint cospanning trees[4] which span all vertex pairs which can be spanned by any tree pair. The two-tree strategy of the short player played with respect to this tree pair will win where possible, and is independent of the chosen pair of vertices. Hence the short player can play and win where possible without knowledge of the chosen vertex pair. Such a strategy is not possible for the cut player.

By duality[5] it is possible to characterize those graphs with two distinguished vertices in which the cut player, playing second, can win against all strategies of the short player. The remaining graphs are those on which the player playing first can win against all strategies of the other player. These graphs differ from those previously discussed by only one branch, and the winning strategies are correspondingly similar.

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* Received by the IRE, May 8, 1961.

[1] M. Minsky, "Steps toward artificial intelligence," Proc. IRE, vol. 49, p. 23; January, 1961.

[2] H. Whitney, "The abstract properties of linear dependence," *Am. J. Math.*, vol. 57, pp. 507–533; 1935.

[3] Two trees are cospanning if they connect the same set of vertices.

[4] More properly two forests—these trees need not be connected.

[5] All of the results hold for matroids. If the graph is not planar, the matroid dual still exists. Thus the roles of the cut and short player are dual locally (*i.e.*, with respect to a given vertex pair), but not globally.

The Wide Tuning Range of Backward Traveling-Wave Parametric Amplifiers*

In a recent paper, Straus[1] discussed the tuning range of backward traveling-wave parametric amplifiers. He has shown that the TEM mode of operation described by Breitzer and Sard[2] can be modified to provide a wider tuning range. The analytical and graphical examination of Straus gives a clear demonstration of the way of extending the tuning range, and also provides a satisfactory explanation of the experimental results of Breitzer and Sard.[2] Nevertheless, the scheme of Straus actually does not fully cover the maximum tuning range, and it is different from the mechanism used in our earlier reported work for achieving wide tuning ranges.[3] In fact, it is possible to extend still further the tuning range of electronically tunable parametric amplifiers in many different ways.

Fig. 1 shows a typical ω-β diagram of the loaded transmission lines of a backward traveling-wave parametric amplifier. The PQ branch belongs to the pump. The P_sQ_s and P_iQ_i branches belong to the signal and idler which propagate in the same transmission line. It is assumed that the periodic

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* Received by the IRE, May 12, 1961; revised manuscript received, May 19, 1961.

[1] T. M. Straus, "Tuning range of the backward traveling-wave parametric amplifier," IRE Trans. on Microwave Theory and Techniques (Correspondence), vol. 9, p. 95; January, 1961.

[2] D. I. Breitzer and E. W. Sard, "Low frequency prototype backward-wave reactance amplifier," *Microwave J.*, vol. 2, pp. 34–37; August, 1959.

[3] H. Hsu, "Letter to Editor," dated September 23, 1959, *Microwave J.*, vol. 3, p. 14; January, 1960.

H. Hsu, "Backward Traveling-Wave Parametric Amplifiers," presented at Internatl. Solid-State Circuits Conf., Philadelphia, Pa., February 10–12, 1960, and at the Internatl. Congress on Microwave Tubes, Munich, Germany, June 7–11, 1960.

H. Hsu, "Wide-Band Electronically Tunable Parametric Amplifiers," GE Co., Syracuse, N. Y.; November, 1959. (unpublished) loading of parametric diodes occurs at intervals of a.

The conditions for backward traveling-wave parametric amplification are[3,4]

$$\omega_p = \omega_i + \omega_s, \tag{1}$$

$$\beta_p = \beta_i - \beta_s. \tag{2}$$

In order to satisfy (1) and (2), the sets of points (P, P_s, P_i) and (Q, Q_s, Q_i) in Fig. 1 are linked by the dotted curves which are parallel to the ω-β curve of the signal and idler transmission line. Graphically, we can determine P, for example, from P_s and P_i, and vice versa.

In Fig. 1, the positions of P_i and Q_i are chosen such that the idler frequency is very close to the cutoff frequency, and thus the idler frequency is essentially constant over the whole tuning range. As is shown in Fig. 1, the signal-frequency tuning range (P_s, Q_s) is larger than 2:1. The tuning range can also be extended further by properly shaping the ω-β curve of the pump (PQ). Fig. 2 shows a tuning range (P_sQ_s) of about 3:1 when the pump characteristic approaches that of a TEM mode. In Figs. 1 and 2, the signal, idler, and pump frequency bands are still separated from each other. Consequently, the limitations on the tuning range imposed by the condition of separation of these frequency bands, as discussed by Breitzer and Sard[2] and Straus,[1] are no longer severe in the schemes of Figs. 1 and 2. In fact, there is considerable freedom in the choice of circuit parameters, such as the relative phase velocities of the transmission lines; and the tuning range can be extended further.

The schemes of Figs. 1 and 2 have several additional advantages. We have chosen ω_i at P_i and Q_i to be equal. Thus, the required pump and signal tuning ranges ($\Delta\omega_p$ and $\Delta\omega_s$) are equal, *i.e.*,

$$\Delta\omega_p = \Delta\omega_s. \tag{3}$$

The TEM mode of operation[2] requires a proportional change in the pump and signal frequencies. Thus

$$\Delta\omega_p = (\omega_p/\omega_s)\cdot\Delta\omega_s. \tag{4}$$

In the modified TEM mode,[1] $\Delta\omega_p$ is smaller than the value of (4), but still higher than the value of (3). Thus, the fractional change in the pump frequency ($\Delta\omega_p/\omega_p$) is reduced in the scheme of Figs. 1 and 2. Furthermore, we can now raise ω_p and ω_i, such that the fractional change in pump frequency becomes smaller. This results in simpler and possibly faster electronic tuning. The noise figure is also better due to the higher ω_i/ω_s ratio.

In the construction of Figs. 1 and 2, the points Q_i actually lie in the second Brillouin Zone.[5] Thus, Q_i is identical to Q_i' (Fig. 1) of the first Brillouin Zone. The sets of points Q_s, Q_i', and Q correspond to the parametric amplification of the backward traveling waves of the signal (Q_s) and idler (Q_i') by a forward pump wave (Q). This type of operation is of particular physical significance because it is a typical microwave analogy of the Umklapp process described by Peierls.[6]

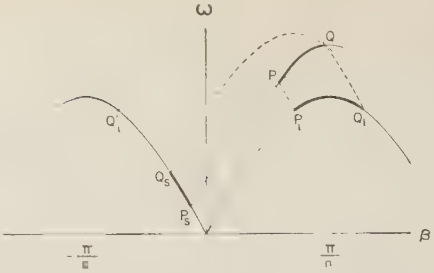

Fig. 1—Graphical illustration of the wide tuning range of backward traveling-wave parametric amplifiers.

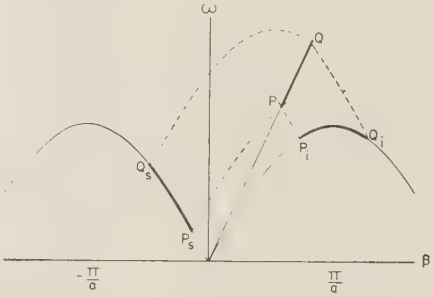

Fig. 2—Graphical illustration showing a further extended tuning range.

The fact that the idler frequency remains essentially constant is characteristic of the schemes of Figs 1 and 2, but these figures are not the only choice. We have achieved various types of parametric interactions with an essentially constant idler frequency in other schemes. For example, it is possible to provide separate idler circuits with a constant idler frequency. It is also possible to operate the idler near the cutoff frequency of the pump circuit when a loaded waveguide is used.

With an essentially constant idler frequency, the signal tuning range is a function of the phase velocities of the pump ($v_{\phi p}$), signal ($v_{\phi s}$) and idler ($v_{\phi i}$). From (1) and (2), we obtain

$$\frac{\omega_s}{\omega_i} = \left[\frac{v_{\phi p}}{v_{\phi i}} - 1\right]\cdot\left[\frac{v_{\phi p}}{v_{\phi s}} + 1\right]^{-1}. \tag{5}$$

By comparing (5) with Fig. 2, for example, we see that the enhanced tuning range is a result of varying $v_{\phi i}$ while keeping $v_{\phi s}$ and $v_{\phi p}$ nearly constant. From (5) or the corresponding graphs reported earlier,[3] the effect of the variations of the phase velocities on the tuning range can be calculated. The result serves as a guide in the design of the microwave structures.

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S. Wanuga
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[4] P. K. Tien, "Parametric amplification and frequency mixing in propagating circuits," *J. Appl. Phys.*, vol. 29, pp. 1347–1357; September, 1958.

[5] L. Brillouin, "Wave Propagation in Periodic Structures," Dover Publications, Inc., New York, N. Y.; 1953.

[6] R. E. Peierls, "Quantum Theory of Solids," Oxford University Press, Oxford, England; 1955.

Correction to "Negative Resistance in Transistors Based on Transit-Time and Avalanche Effects"*

The authors would like to make the following correction to the above paper.[1]

The very last factor (exp $i\omega\tau$) in (5) should be changed to ($1+\bar{m}$ exp $i\omega\tau$).

The authors wish to thank O. Gandhi of Philco for bringing this error to their attention.

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H. Statz
Research Div.
Raytheon Co.
Waltham, Mass.

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* Received by the IRE, April 26, 1961.

[1] H. N. Statz and R. A. Pucel, "Negative resistance in transistors based on transit-time and avalanche effects," Proc. IRE (Correspondence), vol. 48, pp. 948–949; May, 1960.

Correction to "Communications Satellites Using Arrays"*

In the above paper,[1] the author would like to make the following corrections. In Table I, the figures for Stabilized Dish are reversed. The power for $D=60$ feet should be 22.4 mw and the power for 120 feet should be 5.6 mw.

In addition, the cylindrical array of Fig. 3 does not produce exact reinforcement as the following analysis shows. Referring to Fig. 1 of this letter where half of a cylindrical array with an odd number of elements is depicted, let the elements be spaced uniformly along the projected plane aperture.

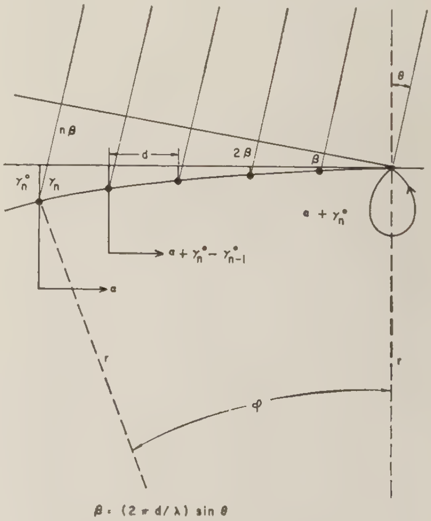
θ
nβ
d
2β
β
γ_n°
γ_n
$\alpha + \gamma_n^\circ$
$\alpha + \gamma_n^\circ - \gamma_{n-1}^\circ$
α
r
r
φ
$\beta = (2\pi d/\lambda)\sin\theta$

Fig. 1—Half of cylindrical array.

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* Received by the IRE, May 22, 1961.

[1] R. C. Hansen, "Communications satellites using arrays," Proc. IRE, vol. 49, pp. 1066–1074; June, 1961.

Suppose also that the connecting line lengths are adjusted to compensate exactly for the cylindrical surface at broadside $\theta=0$. Using the symbols of the figure, the phase correction $\gamma_n{}^0$ for the nth element at broadside is given by

$$\gamma_n{}^0 = r - \sqrt{r^2 - n^2d^2}. \tag{1}$$

The actual departure γ_n of the nth element from the plane aperture is given by

$$\gamma_n = \gamma_n{}^0 \sec\theta. \tag{2}$$

The phase error for the nth element as a function of incidence angle θ is then Δ_n and is given by

$$\Delta_n = (2\pi/\lambda)(\sec\theta - 1)(r - \sqrt{r^2 - n^2d^2}). \tag{3}$$

For small n and for half-wave effective spacing, this is approximated by

$$\Delta_n \simeq (n^2\pi\lambda/4r)(\sec\theta - 1). \tag{4}$$

Here r is the cylinder radius. The angular factor varies as follows:

$\theta=0$	15	30	35	40	45
$(\sec\theta-1)=0$	0.035	0.155	0.221	0.305	1.00

For a practical example, take a frequency of 8 Gc and a diameter of 2 feet. Table I gives the maximum phase error in radians for two scan angles. Note that n is half the total number of elements minus 1. Now if the correction is chosen to be exactly halfway between $\gamma_n{}^0$ at broadside and $\gamma^{\max}$ at $\theta_{\max}$, maximum and equal phase errors occur at $\theta=0$ and at $\theta=\theta_{\max}$, and these phase errors are just half of those given in the table. Silver[2] shows that a maximum quadratic phase error of 0.79 radian ($\lambda/8$) gives a gain loss of 0.25 db; a phase error of 1.58 ($\lambda/4$) gives a gain loss of 1.0 db. For the synchronous example in the original paper, the cylindrical array is satisfactory. To check the two-term approximation of (4), the ratio of the third term to the second term was examined and found to be less than 0.1 for $n=10$ (corresponding to 21 elements). Thus, the approximation is quite good up to a full quadrant.

TABLE I

n	Total Elements	$\theta=30°$	$\theta=45°$
2	5	0.06	0.38
4	9	0.24	1.56
6	13	0.54	3.48
8	17	0.96	6.18
10	21	1.50	9.66

In the equatorial synchronous (stationary) satellite case, coverage requirements limit the number of elements and hence limit available directivity. It should be mentioned that active Van Atta systems should offer major advantages for long-distance space communications where narrow beamwidths, and thus high directivities, could be realized.

Norwood has recently pointed out that the decrease of effective aperture away from broadside of the passive array could be compensated by using an element factor which increased away from broadside.[3]

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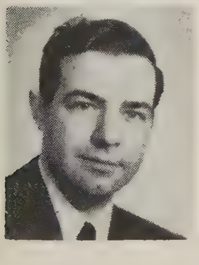
[2] S. Silver, "Microwave Antenna Theory and Design," M.I.T. Rad. Lab. Ser., McGraw-Hill Book Co., Inc., New York, N. Y., vol. 12, p. 191; 1949.

[3] V. T. Norwood, "A Versatile Reflector Design for Passive Satellite Use," URSI-IRE Spring Meeting, Georgetown University, Washington, D. C.; May 1-4, 1961.

Contributors



F. R. Arams

Frank R. Arams (S'44–A'49–SM'55) was born in the Free City of Danzig, on October 18, 1925. He received the B.S.E. degree in electrical engineering and mathematics from the University of Michigan, Ann Arbor, in 1947, the M.S. degree in applied physics from Harvard University, Cambridge, Mass., in 1948, and the M.S. degree in business management from Stevens Institute of Technology, Hoboken, N. J., in 1953. He received the Ph.D. degree in Electrical Engineering (electrophysics from the Polytechnic Institute of Brooklyn in 1961, with a dissertation on cross-relational masers.

During World War II, he served in the Army Signal Corps as Communications Chief of Radio Receiver Station WXH, Ketchikan, Alaska. He joined RCA, Lancaster, Pa., in 1948, where he was Project Engineer on various development programs in microwave magnetrons, traveling-wave tubes, and plasma-filled cavities. From 1953 to 1956 he was employed at the Tube Division of RCA, Harrison, N. J., where he was in charge of the microwave-tube application engineering group. In 1956, he joined Airborne Instruments Laboratory, Melville, N. Y., where he is presently associated with the Department of Applied Electronics as Consultant, concerned with theoretical and experimental work on microwave solid-state devices such as new types of solid-state maser amplifiers, microwave linear and nonlinear ferrite devices, and parametric amplifiers. He now directs programs in microwave ferrite, and millimeter-wave and optical maser fields.

Dr. Arams is a member of Tau Beta Pi, Eta Kappa Nu, the American Physical Society, and the Editorial Board of the *Microwave Journal*.

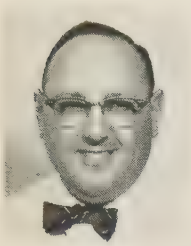
❖

Wolfgang W. Gärtner (M'54-SM'60), for a photograph and biography, please see page 839 of the April, 1961, issue of these Proceedings.

M. I. Grace

Martin I. Grace (S'57, M'59) was born in New York, N. Y., on June 16, 1936. He received the B.S.E.E. degree from the Polytechnic Institute of Brooklyn, Brooklyn, N. Y., in 1958. He is presently completing the requirements for the M.E.E. from the Polytechnic Institute of Brooklyn. From 1958 to 1961 he was an engineer in tue Applied Electronics Department of Airborne Instrument Laboratory where he worked on ferrite devices and backward-wave parametric amplifiers.

In March of 1961, he joined the staff of the Advanced Devices Laboratory of Airtron Incorporated, Morris Plains, N. J. as a Group Leader working on the development of parametric amplifiers and ferrite devices. In 1960 he joined the staff of the Department of Electrical Engineering at the Polytechnic Institute of Brooklyn as a part-time Instructor.



B. Jaffe

Bernard Jaffe was born in Brooklyn, N. Y., on November 28, 1923. He received the B.S. degree in ceramic engineering from the New York State College of Ceramics at Alfred University, Alfred, N. Y., in 1948.

From 1948 to 1955, he worked on ceramic dielectrics and on ferroelectric ceramic transducer materials at the National Bureau of Standards in Washington, D. C. Since 1955, he has been working on piezoelectric ceramics at the Electronic Research Division of Clevite Corporation, Cleveland, Ohio, where he is head of the Electro-Ceramic Section.

Mr. Jaffe is a member of the American Ceramic Society and of the Institute of Ceramic Engineers.

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Sanford A. Meltzer, for a photo and biography, please see page 532 of the February, 1961, issue of these Proceedings.

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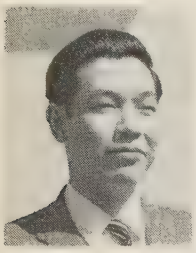

J. Nagumo

Jin-ichi Nagumo (M'60) was born in Tokyo, Japan, on October 14, 1926. He rereceived the Kogaku-Hakase degree in applied physics from the University of Tokyo, Japan, in 1954.

From 1953 to 1959, he was an Assistant Professor of applied mathematics at the Keio University, Tokyo, Japan. Since 1959 he has been an Assistant Professor of applied physics at the University of Tokyo; since 1948 he has been working mainly on the theory of nonlinear oscillations, nonlinear circuit theory and nonlinear electronics.

Dr. Nagumo is Vice-Chairman of the Professional Group on Nonlinear Circuit Theory of the Institute of Electrical Communication Engineers of Japan.

⁂

S. Okwit

Seymour Okwit (A'55, SM'61) was born in New York, N. Y., on August 31, 1929. He received the B.S. degree in physics from Brooklyn College, N. Y., and the M.S. degree in applied mathematics and physics from Adelphi College, Garden City, N. Y., in 1952 and 1958, respectively. He is presently working toward the Ph.D. degree in mathematical physics, Adelphi College, Garden City, N. Y.

From 1952 to 1954, he was in the armed forces assigned to the detection division of the Chemical and Radiological Laboratories of the Army Chemical Center, Edgewood, Md., where he did extensive development work on instrumentation for the detection and analysis of the poisonous "G" nerve gases. Detection instruments upon which he has worked include an infrared scanning system and a system utilizing microwave spectroscopy. He was associated with the radar department of Arma Corporation, Long Island, N. Y., from 1954 to 1955, where he was concerned with boresight on monopulse antennas. He joined the Airborne Instruments Laboratory, a division of Cutler-Hammer, Inc., Melville, N. Y., in 1955, as an engineer in the Department of Electronics, where he was concerned with the design and development of RF, IF, and microwave components and systems. Since 1958, he has been responsible for, and has performed considerable theoretical and experimental work on solid-state devices such as low-loss circulators, low-level ferrite limiters, and cavity and traveling-wave masers. At present, he is a Section Head in the Applied Electronics Department at AIL, and is directing programs in the development of advanced solid-state devices including masers, parametric amplifiers, and novel ferrite components.

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Max J. Schuller (M'60), for a photograph and biography, please see page 840 of the April, 1961, issue of these Proceedings.

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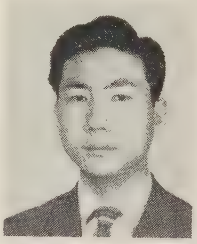

M. Shimura

Masamichi Shimura was born in Tokyo, Japan, on April 5, 1936. He received the Kogakushi degree in applied physics from the University of Tokyo in 1960.

He is now a student in the postgraduate course and is engaged in studies of nonlinear electronic circuits under the direction of Assistant Professor J. Nagumo.

⁂

Samuel Thaler (A'42–M'60), for a photo and biography, please see page 532 of the February, 1961, issue of Proceedings.

Books

Transistor Circuit Analysis, by Maurice V. Joyce and Kenneth K. Clarke

Published (1961) by Addison-Wesley Publishing Co., Inc., Reading, Mass. 438 pages+11 index pages +xiv pages+5 pages answers to problems. Illus. $6\frac{1}{4} \times 9\frac{1}{4}$. $10.75.

From the large influx of technical books dedicated to the theme of tutoring the engineer on the fundamentals of transistor circuitry, it is refreshing to review a book that is so well prepared and presented as "Transistor Circuit Analysis," by M. V. Joyce and K. K. Clarke.

The book is orientated in an academic flavor with suggested reference reading and circuit problems at the end of every chapter. The over-all concise preparedness of the text is obviously derived from the academic teaching background of the authors, the late Maurice V. Joyce and Kenneth K. Clarke, associated with the Electrical Engineering Department of the Polytechnic Institute of Brooklyn. The text provides a continuous development of junction transistor circuitry which would benefit the electrical engineer attempting to establish himself in the semiconductor electronics field. It definitely serves as an excellent textbook for the undergraduate electrical engineer engaged in the study of semiconductor electronics during his senior year.

The first several chapters describe the junction transistor circuit characteristics and then expand these into the circuit equivalent Tee and the Hybrid and the well-known Hybrid-Pi circuit model. The transistor then is treated in its three basic circuit modes of operation (common base, common emitter, and common collector), and the pertinent characteristics and circuit parameters are analyzed. The following six chapters (4–9) provide an excellent presentation of transistor low freqeuncy small signal amplifiers, power amplifiers, power regulators, broad-band amplifiers, and narrow-band amplifiers. It is felt that in the presentation of the high-frequency equivalent circuit a broader expansion into the characteristics of the Hybrid-Pi equivalent circuit would have been beneficial. Perhaps an entire chapter should have been dedicated to transistor high-frequency characteristics.

Chapter 8 presents an extensive analysis into broad-band transistor amplifiers with excellent coverage on the gain bandwidth tradeoff and feedback techniques to attain this end. The chapter also has an excellent presentation on the analysis of the frequency response of the emitter follower circuit. The last part of Chapter 8 deals with the subject of transistor distributed amplifiers.

Chapter 9 expounds on the characteristics of transistors in band-pass, and it is interesting to note that the authors concentrate their effort on the analysis of the transistor characteristics as applied to the circuit rather than dealing with an extensive dissertation into the characteristics of the associated passive elements. Chapters 10–14 deal with the subject of transistors being employed as switches. The reviewers feel that an incorporation of the junction transistor being treated as a stored charge device would have aided many engineers in their understanding of the fundamental concepts of transistor switching theory. The majority of the circuit examples analyzed in the text are very much the "state-of-the-art" techniques. Chapter 15 gives an up-to-date presentation of circuit characteristics of negative resistance devices such as the tunnel diode and the "PNPN" junction transistor. The final chapter, Chapter 16, goes into the analysis of employing transistors in the conventional sine wave oscillator usage. It is felt that the high-frequency oscillator equivalent circuit could have been expanded upon and perhaps one network analysis example given.

This book is definitely recommended for the transistor circuit engineer to serve him as an excellent circuit reference guide. It should prove to be very popular with the engineer embarking into the semiconductor electronics field for obtaining a complete tutorial background on semiconductor circuitry. The book should especially become popular with the undergraduate electrical engineer as a textbook for transistor electronics during his senior year at college.

J. T. Lynch
J. J. Karew
Burroughs Corp.
Paoli, Pa.

IRE Dictionary of Electronic Terms and Symbols (Compiled from IRE Standards)

Published (1961) by the Institute of Radio Engineers, 1 E. 79 St., New York 21, N. Y. 221 pages+4 index pages+x pages. Illus. $6\frac{1}{4} \times 9\frac{1}{4}$. $5.20 members; $10.40 nonmembers.

During the past two decades the IRE has issued over eighty IRE Standards, covering the vast multitudes of fields represented within the IRE Standardization structure. These Standards have been divided approximately equally between Standards on Definitions of Terms and Standards on Methods of Measurements. There have also been Standards issued on graphical and letter symbols. Prior to 1949 these were issued as separate pamphlets. Currently each Standard, as issued, appears in the Proceedings of the IRE.

This Dictionary fills the long-felt need for a compilation of the Definitions Standards under one cover, together with associated letter and graphical symbols. It includes the definitions contained in 37 IRE Standards dealing with electronics terminology and symbology. Thus all Standards in effect as of December, 1959, have been combined in this one volume. Knowing the mass of material put out by the IRE, this reviewer was frankly surprised that it was possible to get it all in such a compact volume (225 pages). Yet they are all there, some 3700 terms, plus five IRE Standards dealing with letter and graphical symbols.

This Dictionary has one definite advantage over other contemporary works, at least with respect to IRE definitions, in that it does not take liberties with printed definitions or notes, but reproduces them verbatim. In other works, modifications are frequently encountered and occasionally the notes are incorporated into the definition, whereas they are intended to be explanatory or complementary. This Dictionary, therefore, preserves the purity of the original IRE context.

The reader should find the inclusion of graphical and letter symbols of particular value, especially in those fields where a profusion of competing, and often confusing, symbols exists. In particular, the semiconductor area is well delineated in both respects. This will prove of great assistance to the novice in this important field, helping him to understand the fine distinctions in usage conveyed by the various combinations of capital and lower-case symbols and subscripts. Possibly a perusal of the remainder of the graphical symbols will convert some readers to a proper usage of the capacitor and relay symbols!

This book will be indispensable to anyone having occasion to deal with legal terminology in the electronics field, as well as to the practicing engineer who wants a handy source of authoritative definitions. It is to be hoped that having established this precedent the IRE will follow at reasonable intervals with either supplements or new editions, adding the later material continually generated in this fast-moving technology.

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Knolls Atomic Power Lab.
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Printed Circuits—Their Design and Application, by J. M. C. Dukes

Published (1961) by Macdonald & Co., Ltd., 16 Maddox St., London, W. 1, England. 196 pages+12 index pages+xii pages+11 bibliography pages+9 appendix pages. Illus. $5\frac{3}{4} \times 8\frac{3}{4}$. 40s. net.

The widespread interest in new ways of fabricating electronic hardware, as indicated by the large development effort, has resulted in many published papers. This situation has created a problem for the practicing engineer who wishes to stay abreast of the capabilities and limitations of the many competing approaches. The book by Mr. Dukes goes a long way toward solving the problem for the field of printed circuit techniques.

The book starts with an introduction which includes a brief historical review and a classification system for printed circuit techniques. The author makes a valiant attempt to define the term "printed circuit." He concludes that it is a poor term but that it is too commonly used to bear substitution.

The book is broken up into two main parts: the first on Manufacture and the second on Design and Application. In the first part a separate chapter is devoted to a description of each of the following classes of techniques: the direction deposition of a metallic circuit on a bare insulating surface, the controlled removal of metal from a previously metallized surface, and methods which combine the formation of the substrate and the detailed circuit wiring. The second class covers the most popular technique now employed for printed circuits, that is, the etched-foil technique. An additional chapter in the first part is devoted to these topics: components for printed circuits, automatic assembly machines, dip soldering, and protective coatings.

The part on Design and Application presents information on the preparation of the circuit layout, and a good review is given of materials for use in printed circuits such as ceramics, laminates, and the conducting materials. There is also a discussion of printed component parts including coils, resistors, capacitors, switches, and commutators for use at low and medium frequencies. The last two chapters deal with strip transmission lines and printed microwave components. The author is obviously "at home" in these two chapters since it is in this area that he has made original contributions. The strong emphasis on microwave components is quite proper because of the increasing importance of high speed circuits, of both the analog and digital types, coupled with the need for small size and low cost components and systems.

A generous number of references (173) to British and American literature is provided. It is easy to find sources of more detail on any of these items discussed. The book is thoroughly cross-referenced. Although the author's experience is British, many of the examples include American products.

Two minor weaknesses are apparent. Only a little over one page is devoted to the rapidly developing field of microminiaturization and slight mention is made of the problems of handling transistors in the printed circuit production process. One small irritation is the use in the text of figure numbers that are condensed over those used to identify the figures themselves.

The author describes the book as "a first primer on manufacturing techniques," and he achieves this objective for the field of printed circuits. The book is recommended to the system and equipment designer who is looking for a general understanding of the problems and techniques of circuit fabrication and for anyone entering the field needing references to detailed information.

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Line Waves and Antennas, by Robert Grover Brown, Robert A. Sharpe, and William Lewis Hughes

Published (1961) by the Ronald Press Co., 15 E. 26 St., New York 10, N. Y. 261 pages+3 index pages +v pages+27 appendix pages. Illus. $6\frac{1}{4} \times 9\frac{1}{4}$. $10.00.

This book, written by professors at Iowa State University and Oklahoma State University, is intended as an introductory text in the general area of electric energy propagation. The first six chapters present a good practical treatment of transmission lines including pulse transmission and reflection. Smith charts are used in the analysis to determine input impedance, line length or load impedance when two of the quantities are known.

The next five chapters treat guided waves, wave propagation and waveguide circuit elements with heavier mathematics involving Maxwell's equations and the various waveguide modes. The discussion of lossy wave propagation deals with lossy dielectrics, poor conductors and skin effect problems.

The last three chapters briefly cover electromagnetic wave radiation, dipole antenna radiation and antenna systems.

There are eight appendixes, covering reference material and handbook information such as transmission line, parameters, characteristics and charts, vector analysis, phase and group velocities and the scattering matrix.

The text is in the second person classroom vernacular. In the more difficult areas the authors make assumptions which lead to appropriate solutions, thus avoiding tedious proofs. Numerous problems are left for the student to solve. The term "current flow," which used quite often, is redundant since current is a flow of electrons or ions. The directional antenna patterns for broadside and end fire arrays on page 238 are drawn with the same shape, which is untrue.

The authors have written a very usable text for classroom instructions with excellent descriptive material and a minimum of complex mathematics. The brevity of the presentation keeps the size of the book small; hence the instructor will be called on more often to amplify the text and help the student with his problems.

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Cleveland Institute of Electronics
Cleveland, Ohio

Time-Harmonic Electromagnetic Fields, by Roger F. Harrington

Published (1961) by McGraw-Hill Book Co., Inc., 330 W. 42 St., New York 36, N. Y. 446 pages+8 index pages+xi pages+2 bibliography pages+24 appendix pages. Illus. $6\frac{1}{4} \times 9\frac{1}{4}$. $13.50.

In essence this book is divided into four parts. The first part reviews some of the basic concepts which are needed for the application of the theory of steady-state electromagnetic waves and fields to the solution of problems in electromagnetic engineering. The second part deals with certain boundary-value problems selected from the theory of waveguides, cavity resonators, antennas, and scattering which can be handled simply by the matching of well-known solutions of Maxwell's equations. The third part introduces the reader to variational and perturbational methods of treating waveguide discontinuities, diffraction, and loaded cavity resonators. And the fourth part provides the reader with an exposition on microwave networks.

The book is easy to read and probably pleasant to teach from. Its subject matter is selected to place in evidence some of the more common mathematical methods used in electromagnetic engineering. At the end of each chapter there are problems which illustrate and augment the material in the text. The topics discussed in the book are timely, but not especially new. Indeed, several other books and monographs that cover the same ground have been on the market for a number of years. However, in general, these other books are intended to satisfy the rather sophisticated tastes of the active researcher, whereas the present book is designed to serve as a senior or first-year graduate text for electrical engineering students.

Unfortunately, the author has neglected to provide the reader with an adequate bibliography of original papers. As a result it becomes difficult for the reader to track down the subject matter to its original sources if he limits himself to the few footnote references that the book contains. Although this detracts from the scholarship of the book, it can be remedied by having the instructor supply the missing information.

This reviewer enjoyed reading the book and considers it a worthwhile contribution to the educational literature of electromagnetic engineering.

CHARLES H. PAPAS
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Theory of Microwave Valves, by S. D. Gvozdover

Published (1961) by Pergamon Press, Inc., 122 E. 55 St., New York 22, N. Y. 450 pages+5 index pages+xiii pages+6 reference pages+25 appendix pages. Illus. $6\frac{1}{4} \times 9\frac{3}{4}$. $12.50.

The scope of this book can be most easily conveyed by repeating here the table of contents:

1) Elements of electrodynamics of cavity resonators
2) Static characteristics of the plane diode
3) Alternating voltage applied to a plane diode; basic formulae of microwave electronics
4) Electronics of the plane diode when the influence of space charge is negligible
5) Application of the total-current method to the analysis of the plane diode
6) The influence of transit effects on noise in a plane diode
7) Amplification of high-frequency signals by a triode
8) General theory of single circuit klystron oscillators
9) Theory of the reflex klystron
10) Introduction to the theory of the multi-cavity magnetron
11) The theory of traveling-wave tubes.
12) Noise in the electron beam; the sensitivity of traveling-wave tubes

The technical level of the book is generally high, and some previous acquaintance with the fundamentals of electrodynamics is assumed of the reader. Graduate students in electrical engineering or physics should encounter no serious difficulty in reading this book.

The major part of the book is devoted to a very thorough and detailed presentation of the theory of the plane diode. The reviewer knows of no other single reference work in which so much of the detailed analysis of the plane diode has been compiled. In the chapter on static characteristics, we are given not only the usual multivelocity analysis of the space-charge limited diode, but also a compilation of detailed single-valued velocity analyses for almost all conceivable cases of electron flow between parallel planes. In the ac analyses, the equivalents of the Llewellyn-Peterson equations and coefficients are derived. In the noise analyses, the usual single-valued velocity assumptions are made. The analyses of reflex klystrons, magnetrons, and traveling-wave tubes are essentially standard and equivalent to those found in many graduate level texts and require no special comment.

Because of its limited scope, this book will probably not be very useful as a text for a formal course in microwave tubes. It should, however, be useful as a rather complete reference on transit-time effects in microwave diodes.

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Lectures on Communication System Theory, Elie J. Baghdady, Ed.

Published (1961) by McGraw-Hill Book Co., Inc., 330 W. 42 St., New York 36, N. Y. 603 pages+13 index pages+xii pages+bibliography by chapter. Illus. 6¼×9¼. $12.50.

Models, analytical techniques, representations for signals and channels, as well as coding and detection rules—all appropriate to the design of a single communication link—characterize the material covered in this book. It has grown from a set of notes used in a special two-week summer session on "Reliable Long-Range Radio Communication" offered in August, 1959, at MIT. Most of the material is based on papers written by the chapter authors and published over the past few years in the Proceedings of the IRE and Transactions of IRE Professional Groups. It is the Editor's contention that the book should serve as a reference book for practicing engineers as well as a textbook for students at the senior or graduate level. Nonuniform quality of coverage, absence of exercises, and the necessity for considerable outside reading to extract the full flavor of the subject matter contribute to making the latter view of the Editor border on wishful thinking. This book does not appear to be suitable as an undergraduate text. On the other hand, practicing engineers and sophisticated graduate students can benefit from this book provided they are appraised of both its many excellent features and its important shortcomings. An attempt at providing this balanced assessment follows.

The introductory chapter presents a realistic picture of the role of mathematical models in the design of communication systems and also sets the stage for the four main divisions of the book. The first short division (Chapters 2, 3, and 10) is concerned with statistical notions and techniques for the analysis and representation of linear systems and signals. It is worth noting that Chapter 2 presents a refreshing approach to probability concepts and their relevance to the way in which probability distributions are measured and utilized in communication system design. A more complete appreciation of R. M. Lerner's Chapter 10 on signal representation by sums of elementary signals may be obtained by reference to his paper.[1]

The second principal division emphasizes the characterization of linear time-variant dispersive channels. Chapter 4 serves to motivate the work of this section, while Chapters 5 and 6 delve into the details of channel characterization for relatively rapid channel fluctuations. Canonical descriptions of the linear time variant channel are given in Chapter 6. Long-term variability and its implications in design are examined in detail in Chapter 20.

The third and largest of the four main divisions is devoted to methods for overcoming multiplicative and additive disturbances introduced into the transmission channel. Diversity techniques for combating fading are discussed in Chapter 7. Statistical decision theory is presented in a lucid manner in Chapters 8 and 9. Chapter 11 is concerned with signal design to combat additive noise, both Gaussian and impulsive. Chapter 12 is an excellent treatment of functional receiver design to overcome both multiplicative and additive disturbances. Coding and decoding and pre- and post-decision feedback for error control in digital transmission are treated with precision and clarity in Chapters 13 and 14. Noise characterization and minimization in receiving systems receive adequate attention in Chapters 15–17. Chapter 19, on analog modulation, concludes this section.

Application of the above theory to communication system design is the avowed purpose of the final section of the book. This materializes only in the form of a philosophy for design. A more detailed discussion of Rake (even beyond that in the fundamental paper of Price and Green[2]) might have provided a more concrete illustration of the results obtainable with the application of the theory espoused. The concluding chapter, covering present trends, is appropriately authored by R. M. Fano, who I am sure has been teacher and counselor to many of the authors. Professor Fano advocates overlapping membership in the computing and communication fraternities to bring the present promises of digital communication to fruition.

The significant shortcomings of the book are found in Chapters 7 and 19. Chapter 7 is, by and large, a rewrite by the editor of D. G Brennan's excellent paper.[3] Unfortunately, the sharpness of the original is dulled in "translation." Chapter 19, on analog modulation, as presented does not integrate well with the close-knit subject matter and crispness of the remainder of the text. Secondly, the exposition is fuzzy and can mislead the unwary. For example, the discussion of "manageable bounds" on the error associated with using the "quasi-stationary" response of a linear network to an FM signal is even more obscure than the Editor's original paper on this subject.[4] In this regard, he invokes a very powerful theorem on asymptotic expansions to arrive at his bounds. After a search and study of the pertinent literature on this subject (Erdelyi, Hardy, Knopf, Bromwich, and DeBruijn) this reviewer is unable to verify the existence of such an unrestricted theorem. The treatment of residual distortion in FM is not given in a useful form. Discussion of Chaffee's FM receiver with feedback is trivial. References at the end of the chapter are inadequate. The most glaring omission is the absence of references to the classic papers of Crosby (experimental) and Rice (theoretical) on noise in FM systems.

Despite the above criticisms, the book can be recommended. In particular it should be useful to the communication system designer interested in gaining insight into how statistical communication theory can contribute to the design of modern communication facilities.

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Murray Hill, N. J.

Electronic Drafting Handbook, by Nicholas M. Raskhodoff

Published (1961) by The Macmillan Co., 60 Fifth Ave., New York 11, N. Y. 233 pages+7 index pages+xiii pages+159 appendix pages. Illus. 6¼×9¼. $14.75.

There was a time, not too many years ago, when a mechanical draftsman could turn to electronic drafting without requiring much, if any, additional training. Not so today. The impressive growth in the complexity of electronic circuitry, the birth of printed circuitry, and the broadening of the standardized graphical symbology have all contributed to making electronic drafting a highly specialize field requiring special skills.

The author has prepared a handbook that is more than just a reference guide for draftsmen and designers working in the electronics field. It is eminently suited to students preparing for a career in electronic drafting and design. It will also be of considerable value as a reference text for engineering students majoring in electronics.

The book is divided into four parts. Part 1, Basic Electronic Information, contains brief descriptions, as well as pictures, of practically all of the electronic and mechanical components used in electronic equipment. Also included in this section is a chapter on such materials as the more common alloys and plastics. All of this information in Part 1 has been thoughtfully arranged in alphabetical order to facilitate reference.

In Part 2, General Electronic Drafting Techniques, the author describes general drafting room practice, including the use of templates and other drawing tools. A chapter on mechanical design, dealing with the layout of components on a chassis, or rack; space and cooling considerations; and other design criteria also forms part of this section.

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[1] R. M. Lerner, "The representation of signals," IRE Trans. on Circuit Theory, vol. CT-6, pp. 197–216; May, 1959.

[2] R. Price and P. E. Green, Jr., "A communication technique for multipath channels," Proc. IRE, vol. 46, pp. 555–570; March, 1958.

[3] D. G. Brennan, "Linear diversity combining techniques," Proc. IRE, vol. 47, pp. 1075–1102; June, 1959.

[4] E. J. Baghdady, "Theory of low-distortion reproduction of FM signals in linear systems," IRE Trans. on Circuit Theory, vol. CT-5, pp. 202–214; September, 1958.

Part 3, Special Electronic Drafting Techniques, is the most comprehensive part of this book so far as drafting information, as such, is concerned. Included are chapters on Schematic Diagrams, Wiring or Connection Diagrams, Wiring Harness Drawings, Outline Drawings, Printed Circuits, Industrial Electronic Drawings, Graphical Representation, and Checking Electronic Drawings. In the chapters on schematic and wiring diagrams, the author has drawn heavily—and wisely, we feel, on the American Standards Association standard Y14.15 for his illustrations. This standard reflects industry's coordinated opinion of what information such drawings should contain, and how they should depict this information. The chapter on Printed Circuits contains considerable design information on this comparatively new and radically different approach to electronic wiring. It might have been well to include in this chapter reference to the printed circuit processes described later on page 288.

In Part 4, Reference Information, the author has gathered together such strictly reference information as: Abbreviations, Symbols, Designations, Tube Basing Diagrams, Copper Wire Data, Transistor Types, Screw Sizes, etc. Also included is a digest of the General Specifications for Military Electronic Equipment.

The material in this book is well organized, thus making the book readily adaptable to classroom use. The information is up-to-the-minute, and the data, for the most part, is from authoritative sources. The art work in the illustrations, of which there is an abundance, is excellent. It is too bad, though, that someone did not caution the draftsman preparing the illustrations on pages 136–140 to use the standard resistor symbol which the author illustrates on page 277. And while we are touching on the shortcomings of this book we should also mention that while the author, in Chapter 8 and Appendix A, gives due credit to the military and ASA as sources for the symbols he has shown, he has overlooked giving similar credit to the IRE. The Institute has done considerable work in this field over the years.

These are, however, small faults in a book that is in all respects an excellent treatment of an important subject. Mr. Raskhadoff is to be commended for giving us a book that is authoritative, comprehensive, and—what may seem strange for a text book—readable.

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Electronics, by Paul M. Chirlian and Armen H. Zemanian

Published (1961) by McGraw-Hill Book Co., Inc., 330 W. 42 St., New York 36, N. Y. 327 pages+7 index pages+xii pages. Illus. 6¼×9¼. $8.75.

Now that many topics of electronics such as circuit theory, feedback, and modulation have become well-developed fields of study, about all that is left to electronics is a study of the physical electronics of active devices and the development of their equivalent circuits. It is in recognition of this shift of emphasis that "Electronics," by Chirlian and Zemanian, is limited to the physical electronics of tubes and transistors together with a development of their equivalent circuits.

The book is intended as a one-quarter or one-semester upper division college textbook for electrical engineering or science students. The first chapters discuss electron ballistics, electron emission, Child's Law, and the vacuum diode. Then follow chapters on semiconductor physics and the semiconductor diode. A brief chapter on gaseous conduction indicates that this subject is considered of decreasing importance.

Using the physical electronics of the earlier chapters, the characteristics of vacuum tubes and transistors are next developed. The remainder of the text deals with the graphical and linear circuit analysis of vacuum tube and transistor circuits. The chapter on graphical analysis efficiently combines the vacuum tube and transistor analysis and contains standard material on bias, load lines, and distortion. The final chapters discuss linear equivalent circuits at a level assuming familiarity with three-terminal network theory.

The text has the strong point of integrating vacuum tube and transistor analysis so that neither one is predominate. It also takes advantage of modern courses on circuit theory now commonly taught to electrical engineers. It does not pretend to do more than furnish a background for understanding the characteristics of vacuum and semiconductor devices and obtaining their equivalent circuits. To following courses must fall the task of developing linear amplifier theory, pulse and trigger circuitry, etc.

The text is extremely well furnished with problems; without a thorough sampling the student will miss a good share of the value of the text. As an example, the 67 problems at the end of the chapter on linear equivalent circuits introduce the concepts of frequency response, cathode and emitter followers, the grounded grid amplifier, and the impedences and gain of a feedback amplifier; none of these appears as subjects in the text. The instructor using this text should use the problems as a springboard for additonal discussion.

Reading of the material on emission and semiconductor physics leaves one with a feeling of frustration not entirely the fault of the authors. As a practical matter they have assumed that the reader has no knowledge of thermodynamics including statistical mechanics. How much better it will be when electrical engineers can approach physical electronics with such a background.

One can always find a number of matters with which to quarrel. Chapter 1 does not take advantage of the modern field background of the college student. The text also does not clearly relate the practical physical world to the ideal one under discussion. Examples are in assuming a uniform field between two parallel plates and then using the results of this analysis to find the path of an electron just missing the edge of one plate. In the Child's Law derivation the basic assumption made is that the slope of the potential curve is zero at the cathode. It is more fundamental to take the assumptions as zero initial velocity at the cathode and an emitter electron supply greater than the space current; from these one can deduce that the initial slope must be zero.

The final chapter on piecewise-linear equivalent circuits is certainly useful from the standpoint of obtaining a given V-I curve for modeling a system on an analog computer. But for analyzing the behavior of a circuit including a nonlinear element the necessary information is often more easily obtained from the segmental approximation to the curve than from a complex network of diodes, resistors, and voltage and current sources.

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Progress in Semiconductors, Vol. 5, A. F. Gibson, F. A. Kröger, and R. F. Burgess, Eds.

Published (1961) by John Wiley and Sons, Inc., 440 Park Avenue South, New York 16, N. Y. 315 pages+vii pages. Illus. 6¼×9¼. $11.00.

The primary purpose of this annual series of volumes is to permit the specialist in a particular area to keep abreast of activities in the various aspects of semiconductors without the need of sifting through the massive literature in the field. We have come to expect that this series will do so within the fairly obvious limitations of a series which consists of a single book of reasonable size per year. The present volume is no exception. In general the papers are critical reviews of seven fields. In several cases, very recent work has been included by the expedient of additions made in proof. Comprehensive bibliographies are included with each article.

In "The Electrical Properties of Semiconductor Surfaces," T. B. Watkins begins with a very brief historical outline, followed by a discussion of a surface model with primary emphasis on germanium. Results of basic theoretical calculations are presented, followed by discussions of the measurement techniques used in surface studies and the applications of surface properties.

In "The Absorption Edge Spectrum of Semiconductors," T. P. McLean gives a review of the theoretical analysis of both direct and indirect transitions. After a discussion of the experimental methods used in making measurements, the properties of the absorption edge of both germanium and silicon are presented in detail. Brief references to work on other materials are given in the historical review which opens the paper and in the concluding summary.

"Magneto-Optical Phenomena in Semiconductors" are discussed by B. Lax and S. Zwerdling. Detailed discussions of magneto-absorption, Zeeman effect of excitons, magneto-absorption of impurities, Faraday effect and magneto-plasma effects—both theoretical and experimental—are followed by a brief description of the experimental techniques used in making the measurements. In this fast-moving field any summary is soon out of date, but an extended note added in proof brings the survey well into 1960.

"Indium Antimonide" by T. S. Moss is a concise survey of this material from preparation to applications. Detailed consideration is given to band structure, optical properties, photo effects and electrical properties. Applications of this material utilizing its photo-response, magnetoresistance and Hall characteristics are discussed in some detail. Potential applications as a low temperature diode and transistor are briefly mentioned.

"The Chemical Bond in Semiconductors" by E. Mooser and W. B. Pearson is a discussion of the intricate relationships between the chemical bond and material properties of semiconductors. A theoretical discussion of "Thermal Conductivity of Semiconductors" is given by J. Appel. R. R. Haering and S. Mrozowski discuss "The Band Structure and Electronic Properties of Graphite Crystals" with particular emphasis on the relationships between these phenomena.

In sum, the present volume continues the tradition of this series in presenting timely topics for those interested in the field fo semiconductors. The writing is good and the book is highly recommended.

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Essentials of Dielectromagnetic Engineering, by H. M. Schlicke

Published (1961) by John Wiley and Sons, Inc., 440 Park Avenue South, New York 16, N. Y. 221 pages+6 index pages+xxii pages+5 bibliography pages+8 appendix pages. Illus. $6 \times 9\frac{1}{4}$. $9.50.

The purpose of this book is to furnish essential facts on magnetics and dielectrics, more particularly on high μ and ϵ materials, and serves as a guide to engineers in solving practical problems with actual available materials.

Chapter 1 deals with idealized dielectric and magnetic materials strongly susceptible to electric and/or magnetic fields such as high dielectric ceramics and ferrites and their effect on circuit elements. The fundamental relationships for practical calculations of electrical, magnetic, electromechanical and transmission line parameters are presented in a concise manner. The numerical examples, comparative tables and nomograms are very illustrative.

Chapter 2 is a brief non-mathematical discussion of ferrimagnetism (ferrites) and ferroelectricity (titanates) with typical materials mentioned only.

Chapters 3–5 are concerned with various classes of applications such as lumped reactive circuit elements (Chapter 3), distributed parameter effects (Chapter 4), and finally, a few selected applications are presented connected with nonlinearity, nonreciprocity and losses of these materials (Chapter 5).

It is neither a physics nor a solid-state book. The material and discussion of dielectrics and magnetics are restricted to the basic phenomena and their applications as a reactive circuit element, rather than to fields of applications. Therefore, it does not present details about a number of fields such as amplifiers, computer and memory applications. The bibliography could have been more complete in connection with some topics.

In general, this book is intended to aid engineering thinking in the realm of dielectric and magnetic materials. The presentation of the various conceptional areas along with actual material data and typical numerical examples makes this book very useful for the practicing electronics engineer and the student intending to enter this field.

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Radio Waves in the Ionosphere, by K. G. Budden

Published (1961) by Cambridge University Press, American Branch, 32 E. 57 St., New York 22, N. Y. 509 pages+13 index pages+xxiv pages+13 bibliography pages+2 appendix pages+5 pages index of symbols. Illus. $6\frac{3}{4} \times 9\frac{1}{4}$. $18.50.

With the publication of this extensive text on "the mathematical theory of the reflection of radio waves from stratified ionised layers" (the author's subtitle), it can be said, really for the first time, that an adequate collection of books treating the ionosphere now exists.[1] As any author must do in writing a book of this kind, Dr. Budden has drawn heavily on the work of many authors published in the periodical literature. But he has himself contributed much to that literature and is eminently qualified to collect it, interpret it, and fill in the gaps.

After two chapters of introductory material, the book is organized according to the following topical outline:

Propagation in a homogeneous isotropic medium
Propagation in a homogeneous anisotropic medium; magneto-ionic theory
Properties of the Appleton-Hartree formula
Definition of the reflection and transmission coefficients
Reflection at a sharp boundary
Slowly varying medium; the WKB solutions
Ray theory for vertical incidence when the Earth's magnetic field is neglected
Ray theory for oblique incidence when the Earth's magnetic field is neglected
Ray theory for vertical incidence when the Earth's magnetic field is included
Ray theory for oblique incidence when the Earth's magnetic field is included
The general problem of ray tracing
The Airy integral function and the Stokes phenomenon
Linear gradient of electron density
Various electron density profiles when the Earth's magnetic field is neglected
Anisotropic media, coupled wave equations, and the WKB solutions
Applications of coupled wave-equations
The phase integral method
Full wave solutions when the Earth's magnetic field is included
Numerical methods for finding reflection coefficients
Reciprocity

In the author's words, it is inevitable that some topics are omitted, though that hardly seems possible after viewing the scope of the coverage. But he points out that he does not treat horizontal gradients, irregularities, reflection from cylindrical structures such as meteor trails and field-aligned ionization, wave interaction, and earth-ionosphere waveguide mode theory. Dr. Budden states that the last named topic is a large one and would fill a book itself. J. R. Wait has recently made a pretty good start in that direction by publishing fifty pages on this subject.[2]

In this reviewer's opinion, the author should have made the effort to restrict himself to conventional and easy to write and say symbols. The Fraktur which he has used is particularly unsatisfactory from this point of view.

Dr. Budden has organized and edited his book very well indeed, and it is indexed and referenced in a very complete yet uncomplicated manner. Given a copy of the book to leaf through, any experienced student of the ionosphere will quickly see that this is a book he can ill afford to be without; but if the publisher's out-of-print record with J. A. Ratcliffe's monograph on the magneto-ionic theory is any example, he is likely to find himself without it.

M. G. Morgan
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Hanover, N. H.

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[1] Notably this book and the following:
S. K. Mitra, "The Upper Atmosphere, Second Edition," The Asiatic Society, Calcutta, 713 pp.; 1952.
J. A. Ratcliffe, Ed., "Physics of the Upper Atmosphere," Academic Press, Inc., New York, N. Y., 586 pp.; 1960.
J. A. Ratcliffe, "The Magneto-Ionic Theory and Its Applications to the Ionosphere," Cambridge University Press, American Branch, New York, N. Y., 206 pp.; 1959.
K. Rawer, "The Ionosphere," Noordhoff (German Edition); 1953. Ungar (English Edition); 1956.
H. Bremmer, "Terrestrial Radio Waves," Elsevier Publishing Co., Amsterdam, Netherlands, 343 pp.; 1949.

[2] J. R. Wait, "Terrestrial propagation of very-low-frequency radio waves," *J. Research NBS*, Pt. D, pp. 153–204; March–April, 1960.

Scientific Russian, by James W. Perry

Published (1961) by Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y. 476 pages+9 index pages+xxvi pages+62 vocabulary pages. Illus. $6\frac{1}{4} \times 9\frac{1}{4}$. $9.50.

Teachers and students of scientific Russian will welcome the second edition of Professor Perry's "Scientific Russian." There are many texts available for the teaching of scientific Russian, but none is more thorough and comprehensive than Professor Perry's work. Even for the intense short course where a briefer text may be almost mandatory, the availability of a comprehensive grammar of scientific Russian is a great help to both student and teacher.

Professor Perry has made many improvements in this new edition. Emphasis on cognates will be found particularly helpful. Updating of the reading exercises will increase student interest and the clearer type face will make easier the task of learning to recognize unfamiliar characters.

S. D. Browne
Mass. Inst. Tech.
Cambridge

Electrical Noise, by W. R. Bennett

Published (1960) by McGraw-Hill Book Co., Inc., 330 W. 42 St., New York 36, N. Y. 270 pages+9 index pages+viii pages+bibliography by chapter. Illus. 6¼×9¼. $10.00.

This is an excellent book that should find wide use as a textbook for undergraduate courses dealing with the physics and mathematics of electrical noise and the role of noise in communication systems. It is recommended reading for the expert as a simple and masterful summary of the field. Throughout the book the emphasis is on the physical sources of noise and on the experimental determination of the quantities discussed. Thus, for example, the concept of spectral density is expressed as a reading of a specified meter in a specified circuit. Fundamentals for analyzing basic sources of noise are covered, and methods of design are stressed.

The book starts with a discussion of the general properties of noise. Useful definitions, such as ideal band-pass transmittance, white noise, and noise bandwidth, are introduced.

A discussion of distributions of noise-wave amplitudes is then presented. The way in which this subject is introduced is in keeping with the book's emphasis: a brief description is given of the measurement of distributions by means of a level distribution recorder. Among the distributions discussed and physical examples given are the Gaussian, Rayleigh, and Poisson distributions.

The noise in vacuum tubes is treated at considerable length, yet unnecessary and tedious mathematical detail are avoided. The treatment of transistor noise is to be particularly commended for its clarity and conciseness. A lucid presentation is given of noise in electromagnetic radiation with application to maser noise. One chapter is devoted to noise-generating equipment, another to noise measurements. In the design of low-noise equipment the previously developed theory is applied to the analysis of various important amplifiers, such as the cascode amplifier and the transistor amplifier.

A treatment of the concept of noise measure is given, showing how it applies to low-gain amplifiers and negative-resistance amplifiers. The last two chapters deal with somewhat more sophisticated mathematical methods of noise analysis, and their application to noise in communication systems. Noise in amplitude, phase, frequency, and pulse modulation systems is treated succinctly and clearly. Each chapter contains an extensive bibliography.

This is a book with a judicious choice of content and mathematical tools for dealing with it. The excellent method of presentation is best characterized by the author's own words: "The intent is not to tantalize the reader by referring too often to methods beyond our scope and at the same time not to exhaust him by exploring irrelevant difficulties."

Hermann A. Haus
Mass. Inst. Tech.
Cambridge

Recent Books

Berman, Arthur I., *The Physical Principles of Astronautics.* John Wiley and Sons, Inc., 440 Park Ave., New York 16, N. Y. $9.25. Designed to furnish an exposition of the basic principles of astronautics at a level suitable for a wide technical audience, and for use as an adjunct text in astronomy and mechanics at an intermediate level.

Dummer, G. W. A. and Robertson, J. M., Eds., *British Miniature Electronic Components and Assemblies Data Annual 1961–62.* Pergamon Press, 122 E. 55 St., New York 22, N. Y. $15.00. The first volume in an annual series containing concise data on miniature components, and information on the effect of potting resins, shock and vibration, and temperature overload.

Legros, Roger and Martin, A. V. J., *Transform Calculus for Electrical Engineers.* Prentice-Hall, Inc., Englewood Cliffs, N. J. $12.00. The first half of the book considers the basic properties of Fourier series, Fourier integrals and Laplace transforms; the second half considers the application of transform methods to linear circuits.

Liller, William, Ed., *Space Astrophysics.* McGraw-Hill Book Co., Inc., 330 W. 42 St., New York 36, N. Y. $10.00. Concerned with astronomical and astrophysical problems investigated from above the atmosphere; a compilation of lectures delivered at the University of Michigan in 1959–1960.

Marshak, R. E. and Sudarshan, E. C. G., *Introduction to Elementary Particle Physics.* Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y. $4.50. Eleventh in a series of "Interscience Tracts on Physics and Astronomy," R. E. Marshak, Ed.

Scanning the Transactions

Have you heard? In an industry which annually produces several billion dollars worth of communication equipment, it is perhaps appropriate to take note here of the remarkable device which, in a sense, is the cause of it all. We refer to the human ear, and to the phenomenon of hearing which enters into so many facets of the communications field. Human hearing is indeed phenomenal. Nerves can scarcely carry 1000 pulses per second, and yet we can hear to 18,000 cycles per second and beyond. With the assistance of a physiological automatic-volume-control mechanism, we can perceive an almost painful sound containing 10^{12} times as much energy as the weakest discernible sound. The trained ear can make remarkably good guesses about the pitch of a tone, and a favored few persons have authentic absolute pitch. An especially attentive ear can act as a wave analyzer in identifying the primary constituents of a complex tone or noise. The ear has a poor memory for loudness. On the other hand, it has a remarkable ability for picking out one desired conversation from amongst a babble. If the ear has an impressive range of capabilities, so must the audio and communications engineers who deal with it. For it has been pointed out that the worker in this field is involved with electric circuit theory, vibration theory, electronics, music, psychology, medicine—and to top it off, architecture. (R. A. Long and V. Salmon, "Current research in communications acoustics," IRE Trans. on Audio, March–April, 1961.)

The future of radar—the phased array? If radar system capabilities have increased tremendously during the last 20 years, so have the severity of radar system requirements. In World War II it was generally sufficient to determine the range, height and azimuth of the target. Today, in addition to dealing with range and resolution requirements of a totally different order of magnitude, it is necessary to determine many other factors, such as path, velocity, acceleration, and what kind of target it is. The time has long since passed when we could rely solely on increasing the power of a radar to give the performance improvement needed. During the past decade attention has turned more and more to other techniques for getting more energy on the target, by either playing with the type of pulse which is transmitted, playing with the method of beam formation, or tinkering with the received signal. In looking to the future of radar and which of the numerous techniques appears most promising, it appears that the electronically steered phased array offers the brightest promise. The basic principle involves feeding power to a large number of individual radiators with complete control of the phase for each element. This leads to a highly flexible system which can generate an extremely high-power beam by viture of the fact that it draws upon a large number of smaller power sources. Indeed, the phased array appears to be the only technique available today for coping with the demands of the space age. (J. S. Burgess, "The future of radar," IRE TRANS. ON MILITARY ELECTRONICS, April, 1961.)

Viewing antennas as information processors is leading to an interesting change in antenna design philosophy which may have fundamental implications for the future. Over the past few years the emphasis has been shifting from synthesizing patterns. Instead, the antenna is coming to be regarded as an information processing device, requiring the application of modern information theory concepts to their design and to the optimization of their performance. In this context, the primary design objective is to maximize the information or data rate. This places the various parameters of the antenna system in a new light and suggests the adoption of unconventional techniques for obtaining unusual performance. Among the techniques under investigation are novel nonlinear methods of processing the outputs of the individual elements of an array. In radar applications various kinds of time, frequency or space coding suggest themselves as a means of improving data rate. One can envision, for example, a self-adaptive antenna system which by means of its computer will automatically adjust the intensity of a scanning beam in such a way as to give greater illumination to a target and less to its surroundings. Whatever the direction these investigations take us, we are certain to hear a good deal more about signal processing antennas in the future. (G. O. Young and A. Ksienski, "Signal and data-processing antennas," IRE TRANS. ON MILITARY ELECTRONICS, April, 1961.)

Abstracts of IRE Transactions

The following issues of TRANSACTIONS have recently been published, and are now available from The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y., at the following prices. The contents of each issue and, where available, abstracts of technical papers are given below.

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Audio

VOL. AU-9, NO. 2, MARCH–APRIL, 1961

The Editor's Corner—Marvin Camras (p. 33)

PGA News—William Ihde (p. 35)

Current Research in Communications Acoustics—R. A. Long and V. Salmon (p. 37)

Despite the appeal of the visual arts, all persons turn naturally to sound for the rapid, thorough, and precise transmission of both practical and esthetic information. Communications acoustics deals with this flow of acoustic information, and with controlling noise that might interfere with it.

Acoustical Measurements on a Home Stereo Installation—John K. Hilliard (p. 41)

This paper describes a two-way 500-cycle crossover loudspeaker system using the infinite baffle principle. A 300-cubic-foot volume is used. Two identical systems are spaced 15 feet apart for stereo reproduction.

A description of the living-room architectural acoustics is included. There are no parallel walls or surfaces, and the splay of the side walls is a minimum of one inch per foot. Reverberation decay charts are provided for different frequencies to indicate the effect of the splayed walls. Sine wave and warble tone curves are shown and sine wave single-frequency levels are plotted for the width and length of the room.

Intermodulation Distortion Meter Employing the Hall Effect—A. C. Todd, J. N. Van Scoyoc, and R. P. Schuck (p. 44)

This paper presents a method of measuring intermodulation distortion produced by a nonlinear system operating in the audio-frequency spectrum. The design of the measuring device is based upon the Hall principle. Transistorized circuitry is used throughout. Both the circuitry employed and the theory of operation are discussed. The instrument is simple to operate and permits the measurement of intermodulation distortion at any frequency on a point-by-point basis within the range of 400 to 20,000 cps. Distortion measurements may be made in two ranges; zero to one per cent and zero to five per cent.

Third-Order Distortion and Cross Modulation in a Grounded Emitter Transistor Amplifier—Helmut Lotsch (p. 49)

The nonlinear modulation characteristic of a transistor is approached by the first terms of a Taylor-series formula and the output voltage is calculated for a suitably-chosen ac-input voltage. For higher frequencies and different working points, the influence of the diffusion capacity and the emitter admittance are illustrated by experimental results. It is shown that —as in electronic tubes—the third-order distortions (harmonic distortion, distortion of modulation, alteration of the degree of amplitude modulation, degree of cross modulation) are closely connected, but unlike the situation in electronic tubes, the distortions disappear at a special working point. The influence of the base resistance and the internal resistance of the signal source are discussed in relation to the appearance of this zero point and the frequency dependence.

In an RF amplifier a transistor is modulated, for example, only by a part of the resonant circuit voltage because of the low input resistance in a grounded emitter circuit. Although this voltage transformation is accounted for, the transistor is inferior to the electronic tube with respect to cross modulation. To reduce the cross modulation in a transistor RF stage, two possibilities are described for correcting the distortions with a fixed or controlled working point using a predistortion or a push-pull modulation. In this case the different influences of a resistance in the base lead, or of a resistance blocked for HF but not for LF in the emitter lead, are discussed.

Contributors (p. 59)

Automatic Control

Vol. AC-6, No. 2, May, 1961

Foreword (p. 95)

The Issue in Brief (p. 96)

On a Property of Optimal Controllers with Boundedness Constraints—H. L. Groginsky (p. 98)

This paper deals with a theory for optimal control systems designed to operate a plant of known characteristics. It is assumed that only limited changes in the system characteristics can be effected by the control variables at the designer's disposal.

It is shown that within the assumed limitations for a wide class of inputs and systems and for a certain class of measures of the system performance, an optimal system behaves as a relay or switched system during the transient period and as a continuous system during periods in which the input is reproduced identically. A procedure is described for determining the switching times during the transient period in terms of the permissible measurements.

A Minimal Time Discrete System—C. A. Desoer and J. Wing (p. 111)

A sampled-data control system with a plant having real poles and limited input is considered. The plant forcing function which will bring the system to equilibrium in a minimum number of sampling periods is desired; this function is called an optimal strategy.

To implement this particular optimal strategy, we define a surface in state space called the critical surface. It is shown that this optimal strategy will be generated by the following procedure: at the beginning of each sampling period, the distance ϕ from the state of the system to the critical surface is measured along a fixed specified direction; if $\phi \geq 1$ (or ≤ -1), then the forcing function for that sampling period is $+1$ (or -1); if $|\phi| < 1$, then the forcing function is ϕ. For a third-order plant, it is shown that the critical surface has certain properties which lead to a simple analog computer simulation.

Theory and Design of High-Order Bang-Bang Control Systems—M. Athanassiades and O. J. M. Smith (p. 125)

A complete analysis and design is presented of a nonlinear controller to minimize the response time of a limited input plant whose transfer function has N real roots.

The design procedure is based exclusively on the concept of the switching hypersurface of the system in N-dimensional state space and on the concept of the "distance function" from the state point to the switching hypersurface.

The linear and nonlinear transformations performed by a nonlinear computer upon the error and its time derivatives, in order to generate the optimal amplitude limited input to the plant, are described in detail, and properties of the switching surfaces, which are subsets of the switching hypersurface, are also described.

Model Feedback Applied to Flexible Booster Control—G. E. Tutt and W. K. Waymeyer (p. 135)

The fundamental control problems in the design of flexible space vehicle boosters center around the control of an aerodynamically unstable airframe in a dynamic wind shear (jet stream) environment. This paper presents a feedback model approach to this design problem which shows promise. This system does not adapt to body bending, but instead is contrived to ignore it.

A conventional attitude control system is assumed in which rigid body control considerations have been used to design the control loops. A model of the plant (airframe rigid body dynamics) is derived. The attitude and rate feedbacks are now synthesized by a combination of actual and model rate and attitude. Bending and similar dynamic effects are filtered from the actual attitude and rate signals as required, and the information thus rejected is supplied from the model of the plant. It is readily shown that the performance of this system in response to commands is substantially identical in all important respects to the original rigid body system.

Terminal Control System Applications—R. K. Smyth and E. A. O'Hern (p. 142)

This paper deals with certain theoretical extensions of earlier work on terminal control techniques and their application to an aircraft landing system. The case considered is of a system having a second-order response from altitude rate command to altitude rate. The terminal time equations for this case are developed together with the various closed-loop weighting functions by transform methods. From the terminal equations developed, the terminal controller equations are synthesized for a two-condition terminal controller which controls altitude and altitude rate at the terminal (touchdown) time. The mechanization of these terminal controller equations are presented.

The flight test results of the terminal control system using the system developed in this paper are described briefly. A comparison between flight test and simulation results is included.

A Parameter Perturbation Adaptive Control System—M. J. McGrath, V. Rajaraman, and V. Rideout (p. 154)

Theoretical and simulator studies of some new forms of a parameter perturbation self-adaptive system are presented in this paper. Here, the response of the control system is subtracted from that of a reference model to obtain the error signal. As in the previous studies, the controllable parameters of the system are sinusoidally perturbed. Somewhat different methods of processing the perturbation and error signals have been employed to obtain the parameter control signal which is used in the automatic optimization of the control system.

Computer studies are made with both random and deterministic input signals and parameter disturbances. The results are compared with the analytical results.

Adaptive Servo Tracking—A. I. Talkin (p. 167)

This paper describes a self-adapted sampled-data radar tracking loop. The tracking loop may be considered to be a low-pass filter with a variable bandwidth. The loop is designed to adapt rapidly to changes in the input signal by monitoring both the apparent error and the loop output.

Results show a mean tracking error 25–34 per cent less than that of a comparable linear system, at a receiver SNR of 10 db.

Transfer-Function Tracking and Adaptive Control Systems—C. N. Weygandt and N. N. Puri (p. 162)

In an adaptive system in which the plant parameters are varying, it is necessary to track or measure the plant parameters. Two separate schemes are proposed for tracking the transfer function of a multi-order system.

The first scheme is based on perturbing the normal process with small amplitude sinusoidal perturbation signal consisting of different frequencies. The tracking system is a closed-loop system.

The second scheme does not depend upon perturbation signal, but does require knowledge of the form of the transfer function of the system. It is more suitable for tracking systems which have a number of first-order lag units connected in tandem.

Precision of Impulse Response Identification Based on Short Normal Operating Records—R. B. Kerr and W. H. Surber, Jr. (p. 173)

An identification scheme is presented for estimating in a short time the impulse response of a system from normal operating records.

Maximum-likelihood estimates of the impulse response are discussed, and a "sufficiency" criterion on the input signal is defined based upon the expected integrated squared difference between the actual and estimated impulse responses. Examples of sufficient and insufficient test signals are given in terms of a "sufficient record length" criterion. Experimental results illustrating this latter criterion are presented.

The time variation of the system parameters sets an upper bound on the useful record length. Some preliminary results relating this time variation to the useful record length are also presented.

Some Techniques of Linear System Identification Using Correlating Filters—W. W. Lichtenberger (p. 183)

Random signals and cross-correlation can be used to determine the impulse response of a system. If, instead of a random testing signal, one is employed which has certain properties similar to the random signal, a linear filter may be constructed which performs the necessary cross correlation. No multiplication is involved, and the output is a continuous function of time. Thus, a single filter obtains the impulse response for all values of time. A disadvantage of this method is that in a practical situation, there is usually a great amount of noise present. This "noise" consists mostly of process actuating signals since the measurements must be made "on line."

A Modified Lyapunov Method for Nonlinear Stability Analysis—D. R. Ingwerson (p. 199)

The Lyapunov stability criterion deals with arbitrarily small disturbances. A generalization of the original theorem which applies to arbitrarily large and arbitrarily small disturbances, and to intermediate conditions as well, is given in this paper.

In contrast to the success that has been achieved in advancing the theoretical concepts of stability by this method, little has been accomplished in the way of formulating practical means for applying them to specific problems. A method which is easily applied to many of the systems encountered in automatic control and which has given good results for numerous examples is presented here.

A Mean-Weighted Square-Error Criterion for Optimum Filtering of Nonstationary Random Processes—K. Sahara and G. J. Murphy (p. 211)

A procedure for use in the design of a physically realizable time-invariant linear system for optimum filtering of a nonstationary random process in the presence of nonstationary random noise is presented. The criterion used to measure system performance is a mean-weighted square error.

It is shown that the use of this generalization of the mean square-error criterion leads to a generalization of the Wiener-Hopf integral equation. A technique for solving this modified Wiener-Hopf integral equation is presented, and the application of the theory is illustrated in an example of the optimum synthesis of a missile interception system.

A General Performance Index for Analytical Design of Control Systems—Z. V. Rekasius (p. 217)

A performance index which enables one to specify the desired response of the optimum system in terms of the differential equation describing the response of an ideal model is proposed.

A simple straightforward procedure of calculating this performance index is outlined in the paper. This procedure consists of solution of a set of linear algebraic equations. Simultaneous solution of these algebraic equations yields the value of performance index in terms of gain and time constants of the actual system. It is then a simple matter to calculate the numerical values of the free gain and time constant parameters for the optimum system (*i.e.*, to minimize the performance index). The procedure of optimization is illustrated by means of an example of a third-order system.

Stability of Servomechanisms with Friction and Stiction in the Output Element—P. K. Bohacek and F. B. Tuteur (p. 222)

Servomechanisms with friction in the output element are often observed to oscillate, even though the Bode diagram indicates stability. This paper investigates the conditions for this instability and the type of oscillation that can occur. It finds that an overdamped system with a lag equalizer is stable if $L<2C/C-1$, where L is the lag ratio and C = static friction + Coulomb friction; with a lag-lead equalizer it is stable if

$$\frac{L}{1+a/b} < \frac{2C}{C-1},$$

where a/b is the ratio of the two zeros of the network. Experimental results that correlate with the theory are also included.

Sensitivity Considerations for Time-Varying Sampled-Data Feedback Systems—J. B. Cruz, Jr. (p. 228)

A synthesis procedure for linear time-varying sampled-data feedback systems is described. The plant and compensators are characterized by transmission matrices first introduced by Friedland. Part of the specification involves a deviation or error matrix for the time-varying plant and an allowable deviation matrix for the closed-loop system. Noise considerations are also included. Using a technique analogous to that of Horowitz which was originally used for fixed multivariable continuous control systems, the digital compensator transmission matrices are derived. The corresponding time-varying digital compensators are realized by means of zero-order hold circuits, switches, resistors, and adders. An example using a digital computer simulation is included.

Direct Cycle Nuclear Power Plant Stability Analysis—D. Buden and R. F. Miller (p. 237)

A power plant with a heat exchanger such as a nuclear reactor substituted for the conventional chemical interburners in a jet engine will cause a considerable change in dynamic performance. The instantaneous power generated by the heat source is not the same as the instantaneous power delivered to the turbine. The basic control problems are analyzed using fixed control parameters and partial derivatives around a given operating point. A mathematical criterion is developed and correlated with power plant test data.

An understanding of the inherent limitations of combining a reactor, or any heat exchanger having a thermal lag, with a basic jet engine makes it possible to devise a means of control. The introduction of an effective operational speed control makes it possible to operate a complete power plant under any desired condition.

Circuit Theory

Vol. CT-8, No. 2, June, 1961

Optimum Design of Single-Stage Gyrator-RC Filters with Prescribed Sensitivity—I. M. Horowitz (p. 88)

The design of low-frequency filters by means of RC feedback around active elements has long been known. The advent of the transistor has renewed interest in this field and has necessitated a more exact synthesis procedure. This is because in the classical design the active element is assumed to be an ideal voltage amplifier with infinite input impedance, zero output impedance and zero reverse transmission. The transistor satisfies the dual ideal assumptions to a considerably lesser degree than the vacuum tube. The sensitivity of the transistor parameters to temperature also requires more attention to be paid to the effect of parameter variations on the filter response.

The paper extends the classical theory in several directions:

1) A synthesis procedure is developed in which the finite input and output impedances and reverse transmission of the active element are taken into account in an exact manner.

2) The freedom that exists is used to optimize the synthesis so as to permit design with a "least active" element.

3) Expressions are developed for the sensitivity of the filter to the four low-frequency active parameters and to the passive parameters. It is presumed that the design specifications include a statement of the extent of active and passive parameter variation and the tolerances on the filter response. The procedure for satisfying such specifications is an integral part of the design procedure.

4) Under the constraint of fixed source and load impedances and desired parameter insensitivity, the design achieves maximum gain.

An example which includes all the above features is worked out in detail.

The principal limitations of the design procedure are:

1) It is restricted to a transfer function of second degree so that if sharper cutoffs are needed, several basic sections must be used, separated by isolating stages.

2) It is best suited to achieve low-pass or moderate band-pass characteristics.

Power Conversion with Nonlinear Reactances—E. Della Torre and M. D. Sirkis (p. 95)

Mixing of several frequencies in any nonlinear reactance having a characteristic that can be represented by a power series is considered. The purpose of this paper is to cite the importance of the nature of the nonlinearity in mixing processes occurring in nonlinear reactances. Power relationships are derived, and limitations imposed by a finite degree of nonlinearity are considered. Restrictions on the source frequencies are found, and it is shown that in practice incommensurability is not required. The special cases of harmonic generation and subharmonic generation are considered.

For the case in which the circuit considered in this paper is identical to that analyzed by Manley and Rowe, the results obtained here agree with theirs.

Solving Steady-State Nonlinear Networks of "Monotone" Elements—G. J. Minty (p. 99)

This paper treats the problem of finding the steady-state currents and voltage drops in an electrical network of two-terminal elements, each of which has the property that its current-voltage-drop graph, or "characteristic," is a curve going upward and to the right. (Thus, "tunnel diodes" are excluded, but nonlinear resistances, current and voltage sources, rectifiers, etc. are permitted.)

The construction methods are specifically designed for digital computation techniques (either automatic or manual). The principal tools are: 1) the application of theorems from graph theory ("network-topology"), and 2) quantization of the variables (permitting them to take on only a discrete set of values).

Some Necessary Conditions for a Non-Negative Unit Impulse Response and for a Positive Real Immittance Function—Paul M. Chirlian (p. 105)

The fact that the unit impulse response of a network is non-negative imposes certain conditions on the real part of the transfer or immittance function. Such conditions are derived in this paper. In addition, when the real part of the immittance function is non-negative, necessary conditions are imposed upon the impulse response. Such conditions are also presented here. These conditions are in a graphical form, which can be utilized without the necessity of lengthy calculations.

The Zeros of Transient Responses—A. H. Zemanian (p. 109)

This paper considers the zeros of the transient responses corresponding to rational Laplace transforms whose poles are all real and whose zeros are allowed to be either real or complex. The possible values for the number of zeros of the transient responses are determined under various assumptions on the Laplace transforms. For instance, when the poles of the transform are allowed to have any multiplicity, the possible values for the number of zeros of the transient response are found in terms of the number of zeros of the transform. On the other hand, when the poles are all simple and the pole and zero locations of the transform are known, a stronger result is obtained.

These results are developed for the function obtained by extending to all time the expression for the transient response that holds for positive time. The possible values for the number of its zeros are determined for positive time and for negative time separately.

Zero Cancellation Synthesis Using Impedance Operators—Don Hazony (p. 114)

Through an extension of Richards' theorem, an RLC driving-point impedance function, Z, is synthesized by a prescribed, realizable, four-terminal network terminated with another driving-point impedance function, ζ, four less in rank than Z. Z is completely arbitrary except that it may not have a pole or a zero at the origin or infinity.

The initial four-terminal network consists of a capacitor, a perfectly-coupled transformer, and an ideal gyrator. Other equivalent networks are derived which do not require transformers and gyrators but in which the cascade nature of the synthesis is lost.

The Effects of Time Weighting the Input to a Spectrum Analyzer—Will Gersch (p. 121)

The effects of time weighting the input to a spectrum analyzer are considered. The spectrum analyzer is assumed equivalent to a bank of similar filters whose overlapping pass bands cover a region of spectral interest and whose outputs are measured at a single instant in time. The term transient selectivity is defined as the magnitude of the envelope of the response of a filter with center frequency $\omega+\Delta\omega$, at the time instant T, to an input $e^{j\omega t}$ over the interval $0 \leq t \leq T$. The transient selectivity characteristics of an arbitrary bank of filters can be achieved using a bank of single-tuned filters and time varying the magnitude of the envelope of the input to the filter bank system. This property is called the time-weighting principle.

Spectrum analyzer systems are employed to detect the presence and specify the frequency of fixed-duration constant-frequency signals immersed in noise. For a system whose objectives include distinguishing the presence of several simultaneous signals, two measures of system performance are the sharpness of the system's transient selectivity and the system's signal-to-noise ratio (SNR). Time weighting functions are presented which can realize arbitrarily sharp transient selectivity characteristics. An equation for the SNR for arbitrary filters and arbitrary time weighting functions is also presented. The transient selectivity and SNR performance for a bank of filters time weighted with a $\sin^N \pi t/T$ weighting function is illustrated.

Stability Margins and Steady-State Oscillations of ON-OFF Feedback Systems—Erik V. Bohn (p. 127)

Exact methods of determining the steady-state oscillations in feedback systems incorporating one nonlinear element of the ON-OFF type have been developed by Hamel and Tsypkin. It is shown that these methods are not generally applicable. A general method is developed which overcomes these limitations, and suitable stability margins are derived.

Impedance Transformation Using Lossless Networks—James D. Schoeffler (p. 131)

Two impedances are said to be compatible if one of them can be realized as the input impedance to a two-terminal-pair lossless network terminated in the other impedance. A uniqueness property of the Darlington realization procedure and the methods of cascade synthesis are used to determine a simple, concise set of necessary and sufficient conditions under which two given realizable impedances can be compatible. Applications are discussed.

Broad-Band Matching Between Load and Source Systems—Daniel C. Fielder (p. 138)

This paper discusses impedance matching between an arbitrary load and a particular type of source network, by means of a lossless two-terminal-pair matching network. The source network consists of an LC ladder in series with a generator resistance. This study is devoted principally to theoretical considerations of low-pass systems utilizing lossless matching networks between source networks and arbitrary load impedances. The present effort is one possible extension of previous work of Fano. Fano's system, however, did not include a two-terminal-pair source network. The value of the present work is derived from an investigation of constraints imposed by the source system and the load, rather than just the load itself.

A Unified Approach to Two-Terminal Network Synthesis—P. M. Kelly (p. 153)

The problem of two-terminal immittance function realization is considered in terms of the reflection coefficient. A conceptually basic method of synthesis is developed which has important implications in exact and approximate synthesis techniques. Consideration of the practical shortcomings of this method lead directly to the standard methods of exact synthesis which are demonstrated to be all applications of the Schwarz lemma. Among the methods considered are those of: Foster, Cauer, Miyata, Brune, Bott-Duffin, Fialkow-Gerst, and Darlington.

Correspondence (p. 165)

Contributors (p. 178)

Communications Systems

Vol. CS-9, No. 2, June, 1961

The Examination of Error Distributions for the Evaluation of Error-Detection and Error-Correction Procedures—T. A. Maguire and E. P. G. Wright (p. 101)

The factors influencing the speed at which data can be transmitted, and those determining the error rate, are summarized as an introduction to a statement in respect to error rates measured. Different applications for data transmission are considered in relation to the amount of error correction which may be justified.

Various forms of error detection and correction are illustrated, and the probability of undetected errors is considered from a theoretical point of view for a random distribution of errors. These results are then compared with records obtained by practical tests using various redundancy arrangements.

It is concluded that there is a substantial advantage in the use of large (500-bit) rather than small (50-bit) blocks for detecting errors. It is also suggested that the practical evidence of error patterns which remain undetected should enable more effective detection designs to be produced.

RF Spectra and Interfering Carrier Distortion in FM Trunk Radio Systems With Low Modulation Ratios—R. G. Medhurst (p. 107)

This paper provides formulas for evaluating RF spectral shape and interfering carrier distortion in connection with FM trunk radio systems having low modulation ratios. Numerical results are given for 1800-speech-channel systems. The curves showing interfering carrier distortion are of particular interest in connection with systems using RF multiplex (*i.e.*, systems consisting of a number of carriers each modulated with a signal built up from a large number of speech channels). Preferred carrier spacings, originally determined for 600-channel systems, have been recommended by the CCIR 9th Plenary Assembly, 1959, for use with up to 1800 channel systems. It appears from the analysis that with these larger numbers of channels, a considerable amount of attenuation by filtering or by isolators will be required to give adequate protection against intermodulation distortion.

Consideration of Nonlinear Noise and its Testing in Frequency Division Multiplex Voice UHF Radio Communication Systems—Leang P. Yeh (p. 115)

In UHF radio communications systems, the thermal noise limits the performance under weak received signal conditions. When the signal is strong, the nonlinear noise (sometimes called the intermodulation noise) may become the limiting factor, It is, therefore, imperative to control the intermodulation distortion contribution from the system components by careful equipment design and from the medium by appropriate choice of system parameters.

In single-sideband systems, nonlinear noise may be attributed to two main causes: 1) transmitter nonlinearity and 2) receiver nonlinearity. Multipath effects in the medium do not seem to produce any nonlinear distortion, except selective amplitude fading or frequency distortion. Amplitude nonlinearity is the sole contributing factor in nonlinear noise.

There is no set rule on the subdivision of nonlinear noise among both the transmitter and the receiver. Equal distribution seems to be a reasonable assumption. In some cases, an entirely different distribution may be desired, according to actual requirements.

How to distribute the transmitter or receiver nonlinear noise among its components depends on the characteristics of the components. The general principle is to have the most economical design on every piece of the components, if possible and practicable.

The nonlinear noise in single-sideband systems may be assumed to consist of only 3rd- and 5th-order products. It is further assumed that 3rd- and 5th-order products contribute to the total nonlinear noise in equal amounts in power.

In frequency modulation systems, nonlinear noise may be attributed to three main causes: 1) transmitter nonlinearity, 2) multipath effect in the medium, and 3) receiver nonlinearity. Both amplitude and phase nonlinearities are equally important in the contribution to the noise and each should be considered carefully.

The subdivision of nonlinear noise may be done in two ways. It may be distributed among the transmitter, the path and the receiver, or among the amplitude and phase nonlinearities. In either way, further subdivision is necessary in order to specify the amplitude or phase linearity requirements for the various components of the system.

There is, again, no set rule on the distribution of nonlinear noise among the various causes. The same principle as applied to single-sideband systems as mentioned before may be used for frequency-modulation systems.

The nonlinear noise in frequency-modulation systems may be assumed to consist of only 2nd- and 3rd-order products. It is further assumed that 2nd- and 3rd-order products contribute to the total nonlinear noise in equal amounts.

Methods for performance evaluation, based on signal-to-nonlinear-noise ratio, are given and sample calculations are made to illustrate the methods.

In the test of a complete system, either two-tone or noise loading tests may be used. Assuming that only 3rd-order nonlinear noise is predominant and that a peak factor of 10 db for random noise is chosen, the noise loading test signal-to-nonlinear ratio is 8 db higher than the two-tone test ratio if the rms power in the two tests are equal. However, if the peak power in the two tests is equal, both ratios are the same.

Model of Impulsive Noise for Data Transmission—Pierre Mertz (p. 130)

It has often been found more necessary in the engineering of data transmission systems to consider impulsive noise than conventional Gaussian white noise. A model is proposed for the impulsive noise, which describes empirically an amplitude distribution and a time distribution. Because the latter has been described in experimental work principally in terms of error occurrences, the description is translated into these. The notable characteristics of impulsive noise are that at low occurrence frequencies the amplitudes are much larger than for Gaussian noise, and that impulses or errors tend to be more "bunched" than expected from a Poisson distribution.

Diversity Combining for Signals of Different Medians—J. Granlund and W. Sichak (p. 138)

Over-the-horizon communication systems normally use two identical antennas at each end. It is shown that an asymmetrical arrangement, for example,

60′(   )60′
30′(   )30′

is better than a symmetrical arrangement when both antennas at one end are used for diversity reception and the larger antenna at the other end is used for transmitting. This arrangement is important because for a given performance it costs less than the symmetrical arrangement. Depending on the exact relationship between cost and antenna gain, the cost is a minimum when the difference in antenna gains lies between 3.2 and 4.8 db. Statistical performance for various combining methods and degrees of diversity are presented. As for the case of equal medians derived previously, selector diversity combining is decidedly inferior to equal gain combining, which in turn is about one db worse than maximal ratio combining.

The "instantaneous" SNR's (applicable to data transmission) are derived and compared to the usual short-term SNR's applicable to telephony.

Diversity Reception for Meteoric Communications—A. W. Ladd (p. 145)

One of the first goals of the research effort on meteoric communications was to establish the advantage, if any, of diversity reception.

Three types of diversity were investigated: frequency, space, and polarization.

Nearly perfect correlation of the signals was found for frequency diversity reception with a frequency separation of 4 kc and for space diversity reception for antenna spacings of up to 1200 feet.

Only polarization diversity appears to provide any advantage. Two identical eight-element Yagi receiving antennas were erected, one horizontally polarized and the other vertically polarized. The transmitting antenna was horizontally polarized. Analysis of the data shows that about 34 per cent of the signals on the vertical antenna equal or exceed in amplitude the signals on the horizontal antenna, but the shapes of the bursts on the two antennas are identical in most cases.

It is concluded that there is not enough increase in system performance to justify the use of any of the three types of diversity.

Digital Computer Simulation for Prediction and Analysis of Electromagnetic Interference—D. R. J. White and W. G. James (p. 148)

A digital computer simulation program is described for use by communications systems and equipment designers who must consider electromagnetic interference. The program determines the interference experienced by a test receiver in a signal environment resulting from its associated transmitter, a large deployment of potentially interfering transmitters, and by atmospheric and cosmic noise sources. Simulation models are designed to represent such transmitter characteristics as antenna gain and scan patterns, polarization and emitted power spectrum; other models represent propagation phenomena such as scattering, reflection, fading and tropospheric refraction; and such receiver characteristics as antenna gain patterns, frequency selectivity and demodulator transfer characteristics. Signal acceptability criteria are included to permit system scoring. Program flexibility is stressed so that optimum system design may be achieved through rapid evaluation of successive approximations.

Preliminary Study of a Miniature Under-Water Cable System—B. G. King, G. Raisbec L. O. Schott, and L. R. Wrathall (p. 159)

Certain aspects of feasibility of a miniature submarine cable-transmission system have been studied. The system is small and light, and designed for use in military applications as an expendable item where submarine cables of conventional design would be uneconomical.

It weighs about 125 pounds per mile, transmits 1.35 million pulses per second of a pulse-code modulated (PCM) signal, and is powered by 4.5 ma with a voltage drop of about 2 volts per mile.

Several armorless cables were tested. All have a steel core with a layer of copper for the center conductor, and extruded polyethylene dielectric. They differ in the way in which the center conductor is fabricated, in the materials of the outer conductor, and in the way in which it is held in place over the dielectric.

The transistor repeater uses one transistor and eight passive components. It has a 17-db gain and an output of 0.8 volt into a 75-ohm line.

The repeater housings are hollow cylinders of beryllium copper, $2\frac{1}{8}$ inches by $\frac{7}{16}$ inch. The insulation of the transmission line is joined to the ends of the housing by an adhesive and by a mechanical seal. The cable tension is transferred to the housings by hollow ceramic insulating cones. The housings were tested in 13,200 psi hydrostatic pressure and to 120 pounds axial tension.

A system of five repeaters in 18,000 feet of line was laid in Sandy Hook Bay and was operable for thirteen months.

Development of Sydney, Nova Scotia-St. John's, Newfoundland Canadian National Telegraphs Microwave System—C. J. Bridgland, A. Piechota, and B. P. MacKenzie (p. 165)

A 650-mile radio-relay system composed of 22 "line-of-sight" paths was constructed to supplement the Canadian National Communications between Sydney, Nova Scotia, and St. John's, Newfoundland. Relay repeater points were chosen by means of all available contoured maps and on-site surveys of the various points, bearing in mind radio transmission characteristics and also accessibility for maintenance. All the radio paths were field-tested to confirm their transmission capabilities. The over-water hop between Cape North and Red Rocks, which is 69 miles long, required careful consideration, and special arrangements were made to ensure that this hop would provide a satisfactory performance. Standard Telephones and Cables Ltd., were requested to provide this system using their latest equipment. This is 5-watt equipment working on 4000 Mc and able to carry the equivalent of 600 toll quality message circuits or one video program.

To handle the present Canadian National requirements, three channels were installed in an eastward direction and two in a westward direction. The system is divided into three sections with back-to-back terminals at Corner Brook and Gander for general communications and television branching circuits. Each section has a separate comprehensive supervisory control facility for providing dual information and controls at both section terminals.

Analytical Prediction of Electromagnetic Environments—W. H. Tetley (p. 175)

The problem of transmitting digital data through electromagnetic environments of high ambient-pulse density is one of growing concern. The appearance of pulsed radar in the 10-mw range, and sensitive receivers in the −100-dbm range, will aggravate this situation. This paper discusses three efforts made by the government to predict the status of future environments. In all cases, the basic technique of analytical prediction calls for the solution of mathematical models by digital computer. Results from these analyses are useful to the designer of future systems as well as to the operators who must use them. The responsibility of keeping the signal congestion within bounds rests with the designer and user alike.

Correspondence (p. 186)

Contributors (p. 190)

Education

Vol. E-4, No. 2, June, 1961

Editorial—W. R. LePage (p. 47)

Today's Dilemma in Engineering Education—Gordon S. Brown (p. 48)

The present wide-scale activity to increase the science content of engineering curricula can, if not skillfully accomplished, result in the teaching of science, and not the engineering of science, to engineers. The changes experienced in the substance of the curricula are sometimes so great that faculties encounter great difficulty in providing worthwhile engineering examples to support their presentations of engineering science.

Programmed Learning in Engineering Education—A Preliminary Study—E. M. Williams (p. 51)

A recent study of programmed learning, including experimental use in an electrical engineering department, indicated that the most fruitful application of teaching machine methods is in the presently nonprogrammed or loosely programmed hours spent by students outside classroom or laboratory periods. Programs already developed for use in this study have been concerned with analytical skills; further programs under development are concerned with concepts. Larger scale experiments are planned in which additional questions can be answered, particularly as to whether exposure to programmed instruction adversely affects the capacity of the student to learn independently.

TV Production Techniques and Teaching Efficiency—John B. Ellery (p. 59)

Educators who venture into the realm of television immediately encounter this question: What equipment is required, and what can be done with it? This paper attempts to provide some basis for an intelligent answer.

In designing the research from which this report derived, attention was focused upon basic television production techniques. A series of instructional segments were produced utilizing these techniques; a second series was subsequently produced with the same instructors and subject matter, but with more elaborate techniques. The two series were then presented for viewing by various student audiences. A control group viewed the first series; an experimental group was shown the second series. Preliminary knowledge of subject matter was determined by a pre-test; degree of learning and retention were measured by an immediate post-test, and a delayed post-test. Those data were then analyzed by means of standard statistical instruments.

In collating and appraising the obtained results it was apparent that a one camera production, with true flat lighting, utilizing close-up camera coverage and a modicum of technical skill and imagination, was as effective as the more elaborate production in ordinary lecture-teaching situations.

An Experiment in Laboratory Education—G. Kent and W. H. Card (p. 62)

A departure from traditional forms of undergraduate laboratory education has been incorporated into the electrical engineering curriculum at Syracuse University. In this paper is presented a summary of the reasons for this innovation, a description of the course, and an evaluation of our experiences with it.

As curricula in electrical engineering become more science centered, it is essential that the undergraduate engineering laboratory take as its prime objective the development of skills requisite to the planning and execution of meaningful experiments and the promotion of an understanding of the relationships between theory and experiment. Briefly, the objective is an education in the experimental aspects of scientific method.

This objective has not been well served in the past by the traditional laboratories. Too frequently, student motivation has been poor enough to limit substantially the learning process, and the typical experiment was not likely to afford an opportunity for education in science.

To attempt to fulfill the objectives stated, a separate course in laboratory was initiated. The separation of the laboratory from its traditionally dependent role was expected to permit greater freedom in the technical content of the course and to emphasize the importance of the laboratory to science. The plan of the course was inspired by the belief that motivation, the prime force in the learning process, is determined in part by the significance of the experiments the student is asked to perform, and that an education in science can be obtained only by the exercise of its method. Accordingly, the experiments were conceived as nontrivial real engineering problems whose solutions demand independent study and planning on the part of the student. The technical content of the experiments was arranged to constitute an organized development of scientific knowledge.

Consistent with this general conception, the course is built around a sequence of problems which the student is expected to solve. These assignments state the problem and discuss its origin and significance. A list of apparatus, references to the literature, and occasionally some experimental hint in the form of a provocative statement are given. The students plan their experiments and proceed with them at their own pace. The only time limitations are that a reasonable number of projects must be completed during the course. In addition to keeping laboratory notebooks, the students are required to prepare several specific kinds of reports. In contrast to the common practice of marking solely on the report, grades are determined by total laboratory performance.

The evaluation of this program is a continuous process. Although at this date no conclusive judgments can be made, early indications of student response have stimulated great enthusiasm among the teaching staff. We are confident that progress toward our objectives is substantial.

The Computer Revolution in Engineering Education—Robert E. Machol (p. 67)

The ready availability of high-speed digital computers has wrought a fundamental and unprecedented change in engineering education. Described herein are one university's experiences with a small digital computer, on which thousands of undergraduates have been taught to program within the past year. A new approach to the teaching and administration of computers is required, as is a new approach to almost every aspect of the engineering curriculum. The shape of things to come is briefly examined.

Engineering Education in Canada and the Co-operative Electrical Engineering Program at the University of Waterloo—B. R. Myers and J. S. Keeler (p. 71)

Although co-operative engineering is practiced at several universities in the United States, that at the University of Waterloo is unique in Canada. The baccalaureate program requires five years of continual attendance, during which the student spends alternate three-month periods in school and in industry.

A distinctive feature of the plan is the maintenance of a Co-ordination Department within the University organization. Staffed by senior professional engineers, this department acts as liaison between industry and the students.

Two programs of study are offered in the undergraduate electrical engineering curriculum. One of these is designed for the heavy electromechanical and power systems engineer. The other embraces electronics, communication and computery disciplines, with a greater concentration of theoretical studies.

Although the University is still in its infancy, both industrial and student acceptance of the co-operative plan has exceeded initial expectations. There is every indication that co-operative engineering education will rapidly assume a dominant role in the Canadian academic scene.

Letter to the Editor—Samuel Seely (p. 79)

Contributors (p. 80)

Electron Devices

Vol. ED-8, No. 3, May, 1961

Concentration-Modulation Electron-Beam Devices—Herbert Lashinsky (p. 185)

Electron-beam devices are considered in which a form of concentration modulation, as defined by Gabor, is utilized. In the devices described here a scalloped electron beam is produced by a combination of crossed electric fields and a magnetic field, and strikes a collector after passing through a fixed aperture. The points of minimum width of the scalloped beam are "images" of the cathode which are reproduced along the longitudinal axis of the system by virtue of the cyclotron motion of the electrons. The application of an additional alternating electric field, parallel to the fixed electric field, causes a periodic variation in the longitudinal position of the cathode images, giving rise to an alternating component in the current which reaches the collector. Concentration modulation is compared with other modulation methods. Transit-time limitations are evaluated and possible applications are considered, including frequency multiplication at microwave frequencies. The use of the concentration-modulation technique in modulating a high-density electron beam at audio frequencies in an experimental system is described.

A Stagger-Tuned Five-Cavity Klystron with Distributed Interaction—Hellmut Golde (p. 192)

This paper describes the operation of a five-cavity klystron with distributed interaction using stagger-tuned cavities. A bandwidth of 64 Mc with a gain of about 30 db at 40 per cent efficiency is typical of the performance of the amplifier.

Electron Beam Coupling in Interaction Gaps of Cylindrical Symmetry—Garland M. Branch, Jr. (p. 193)

In a ballistic analysis in which space-charge effects have been neglected, the method of describing the performance of re-entrant cavity resonators in terms of beam-coupling coefficients, beam-loading conductance ratios, the shunt impedance R, and the cavity quality factor Q has been generalized and extended for the treatment of any kind of resonator with electric fields of arbitrary spatial distribution. As one consequence, the properties of resonant helix sections and cavity resonators can be directly compared in terms of the same physical concepts.

Noise Temperature in Distributed Amplifiers—A. Yariv and R. Kompfner (p. 207)

The subject of noise generation in certain types of RF amplifiers is treated. The different physical mechanisms by which noise is generated within the amplifier are discussed. Expressions for the "effective source noise temperature" are derived for distributed amplifiers of the maser, parametric, and tunnel type.

Traveling-Wave Tube Analysis of the Adler Tube—R. W. Fredricks (p. 212)

The cyclotron waves on an electron beam in the pump field of the Adler tube are studied with respect to their circular polarization. It is found that positive and negative circularly polarized beam waves are coupled through the pump electric field. As a consequence of the coupling, the small signal traveling-wave analysis leads to the conclusion that the positive circularly polarized beam wave is comprised of the fast signal wave and all idlers of frequencies $n(\omega \pm \omega_p)$ where n is an even integer, while the negative circularly polarized wave is comprised of all idlers with odd integral values of n. This information appears to be new, and can perhaps be used to design input and output couplers which discriminate against unwanted idler waves.

Bridge Measurement of Tunnel-Diode Parameters—W. Howard Card (p. 215)

A specific bridge measurement technique is presented for measuring the important small-signal parameters of the tunnel diode at frequencies up to 100 Mc and at all significant operating levels. Particular attention is paid to the problem of biasing the tunnel diode to eliminate instability in the negative resistance region which would otherwise prevent significant measurements being made in this region. Requirements for stable bias circuits are analyzed in detail and specific criteria for stable operation given.

A circle diagram method is presented which allows the significant parameters to be determined from a set of measurements made for a sequence of bias voltages, at a chosen frequency. From the results, curves of shunt capacitance and conductance as a function of bias voltage may be plotted.

Measurements made using a Wayne Kerr Type B.801 VHF Admittance Bridge on a particular tunnel diode are presented. The experimentally determined capacitance vs voltage curve is found to agree closely with the theoretical curve of the normal junction diode, with no pecularities through the negative resistance region. Further results show that approximate parameter values may be obtained even when oscillatory or bistable behavior prevents satisfactory measurement in the negative resistance region.

Four-Terminal Analysis of the Hall Generator—D. L. Endsley, W. W. Grannemann, and L. L. Rosier (p. 220)

The four-terminal parameters of the Hall generator are derived and then used to develop expressions for input impedance, output impedance, current gain, and voltage gain. The theoretically determined expressions are then verified for a Hall generator using indium antimonide. The four-terminal equations are given as a function of conductivity, Hall constant, temperature, magnetic field, and dimensions of the material. Thus, the designer may use these expressions in the application of Hall-effect devices.

Focus Reflex Modulation of Electron Guns—Kurt Schlesinger (p. 224)

High resolution and low drive features have been successfully combined in a new type of electron gun for cathode-ray tubes. The gun has a spot-defining aperture of 0.007 inch upon which emission from a large cathode area is concentrated by a retarding electron lens. This unit modulates the beam by electron reflection, while focusing it upon the aperture ("Focus Reflex Modulation").

Immediately ahead of the aperture, a modulated virtual cathode is formed with an emission capability of over four amperes per square centimeter.

A 1000-μa beam with a 6° divergence is controlled by a signal of 12 volts centered at ground potential. Highlight brightness of 250 foot lamberts was read at 17,500 volts, while more than 500 lines were resolved on a television test pattern.

In more recent forms of the FRM gun, 1600 μa are measured in the screen return, out of 1800-μa cathode current. This is 88 per cent over-all transmission, using the same defining aperture (0.007 inch). 18 volts of drive signal will completely modulate the above current.

Anode Effect: the Influence of Electron Bombardment of the Anode on Flicker Noise—H. J. Hannam and A. Van Der Ziel (p. 230)

Experiments are presented which indicate the existence of two types of flicker noise in vacuum tubes with oxide-coated cathodes. The first is "normal" flicker noise that is present for anode voltages below 10 volts; the second is the "bombardment-enhanced" flicker noise that is added when the anode voltage is above 10 volts. It seems that the latter can be attributed to the arrival of neutral oxygen on the cathode. Since most pentodes and triodes operate with anode voltages above 10 volts, the "bombardment-enhanced" flicker noise should be a rather common source of flicker noise in these tubes.

Experimental Investigation of Large-Signal Traveling-Wave Magnetron Theory—J. R. Anderson (p. 233)

Experiments conducted on a beam-type backward-wave amplifier which closely approximates the theoretical thin-beam model used in the large-signal analysis of Sedin have resulted in gain and phase shift characteristics which are in good quantitative agreement with the adiabatic portion of both the Sedin and Gandhi-Rowe theories. Efficiencies approaching the theoretically-predicted maximum have been observed. By driving the amplifier to very large signal levels a conversion efficiency for power available from the initial potential energy of the beam of 63 per cent was obtained with a corresponding value of 45 per cent for the total electronic efficiency. An important feature of this experimental amplifier is the electron gun design which is based on a theory by Kino. That this gun is capable of producing a well-confined, rectilinear-flow thin beam is demonstrated by visual observations of the beam thickness which indicate that ω_c/ω_p is as low as 1.17, a value close to that for a laminar-flow Brillouin beam ($\omega_c=\omega_p$).

Contributors (p. 240)

Industrial Electronics

Vol. IE-8, No. 1, May, 1961

An Event Recorder Using Transistor Switches—J. W. Streater (p. 1)

An improved event recorder has been developed which is capable of resolving the time-relationships among two-state events to within two milliseconds. Conducting styli, writing on electrosensitive chart paper, are switched on or off by transistor circuits functioning as non-mechanical relays having fast response, high sensitivity, and minimum size.

A Device to Determine the Number of Turns and the Presence of Short-Circuited Turns on Cylindrical Coils—Walter F. Praeg (p. 5)

A device to measure the number of turns and the presence of short circuits between turns is described. It will measure, depending on the construction of the magnetic comparator, cylindrical coils with or without a ferromagnetic core. The accuracy for the number of turns measured is ±0.1 per cent. Short-circuited turns, either intentional or accidental, affect only slightly the accuracy of the measurement of the number of unfaulted turns. On coils without an iron core, the presence of one short-circuited turn of No. 25 AWG copper wire can be detected.

Transistorized Switching Control of a Variable-Speed DC Motor—Jack Allison and Paul Vergez (p. 19)

Where a dc motor is supplied energy from a storage battery or other fixed voltage source, variable-speed operation is usually accomplished by adding resistance in series with the motor supply. In this type of control, only part of the total energy delivered by the source is available at the motor to do useful work. The balance of the energy is converted into heat by the series resistance and is lost.

A more desirable approach to speed control, as presented in this report, is to insert a switch rather than a resistor in series with the motor's supply. Here the switch would be opened and closed at regular intervals which would represent infinite or zero series resistance, respectively. In either state, the switch would present no energy losses to the circuit. The motor speed varies with the percentage of time the switch remains closed.

The latter system has the advantage that for a given speed setting, variations in load will not cause fluctuations in speed due to IR drop in any series resistor.

The transistorized switching circuit described in detail in this report represents an efficient method of switching the motor supply current for good speed control. The laboratory model, which gave very satisfactory performance, was designed to control 20 amperes at 24 volts, or approximately a one-half horsepower motor. This rating may be increased with only minor modifications to the circuit.

A Transistorized Tension and Loop Control—T. E. DeViney (p. 24)

With the introduction of power semiconductors, it is possible to accomplish many functions statically that were previously accomplished with electro-mechanical devices. The use of static components results in improved performance with reduced maintenance. The tension and loop control described in this paper features the use of static circuits.

High-Speed Welder for Crossbar Switch Contacts—J. S. Gellatly and R. Spillar (p. 30)

A novel-design welding machine has been constructed to attach the precious-metal contacts required on the switch springs of the crossbar-type telephone central office equipments. Parts are carried through the various checking stations and the multiple welding nest by a geneva-driven high-speed transfer mechanism. The electronic weld control is a 20-unit modular minimum-size packaged capacitor discharge welder utilizing circuits designed to provide a high degree of reliability with semi-skilled electrical maintenance. Carded units of ten switch springs are transferred through the welding nest where 20 contacts are fed, welded, clipped, and checked on $\frac{3}{4}$-second cycle. The speed of 100,000 welds per hour permits this machine to replace 20 previous machine units, thus realizing large manufacturing-cost reduction.

A Digital Storage "Language" for Engineering and Production Information—William S. Bennett (p. 36)

In addition to the present uses of electronic data processing machines in computation, business accounting, simulation, literature retrieval, and the like, these devices could also be used as a central repository for the storage and rapid retrieval of the information we now put on engineering drawings, specifications, process sheets, bills of material, and so forth. However, the data formats commonly used in computation and accounting do not appear to be adequate to the retrieval problem involved, while literature retrieval methods do not have the precision required in production work. A data format or "language" is proposed which is loose enough to contain all possible engineering or production information, but precise enough to permit accurate retrieval. The price paid for these features is the formulation of a large dictionary of identifiers, and some inflation of storage requirements.

Military Electronics

Vol. MIL-5, No. 2, April, 1961

Frontispiece—James M. Bridges (p. 29)

A New Generation of Radar—James M. Bridges (p. 30)

The Future of Radar—John S. Burgess (p. 32)

In this paper an attempt is made to forecast the direction in which the radar state-of-the-art will aim. The paper will begin with a description of a few of the radars of World War II, to set the stage for a comparison and evaluation of the various techniques that have been added.

Since World War II, various components and techniques developments have been designed for our more modern-day radar, and a tremendous increase has been realized in capability for handling smaller, faster and more distant targets. Particular emphasis is placed on the problems of high resolution, discrimination and pattern recognition.

The effect of our entry into the space age on the design of radar equipments will be discussed. These new radars must cope with problems which are at least an order of magnitude greater than the air-breathing threat in all of its aspects.

The conclusion made is that the phased-array type of radar offers the only long-range solution to the complex problems faced today by the radar engineer. Its combination of flexibility, limitless power, high-frequency capability, electronic scanning, etc., makes it the only logical choice for the future.

High-Power Traveling-Wave Tubes for Radar Systems—J. A. Ruetz and W. H. Yocom (p. 39)

Data obtained on high-power traveling-wave tubes at *S* and *C* band indicate performance suitable for the final amplifier in a wide bandwidth phase coherent radar transmitter. Static phase measurements demonstrate the capability of parallel operation of tubes and the feasibility of use in pulse compression systems. Gain and power output data show that for the most efficient operation a programmed drive is needed. Data taken at constant drive power displays a compressed gain variation and a somewhat lower output. An extrapolation of present data indicates the feasibility of obtaining 25- to 30-per cent bandwidth in high-power traveling-wave tubes with other improved characteristics.

Automatic Frequency Control of Magnetrons—Austin R. Sisson (p. 45)

A practical AFC system for both *X*-band and *Ku*-band magnetron radar transmitters has been developed. This system meets the needs of three radar systems currently in production. Frequency stabilization is accomplished by electronically controlling the magnetron load impedance. Therefore, the magnetron "pulling figure" is put to use.

The closed loop AFC system maintains frequency stability to better than ±2 Mc at *Ku*-band and ±1.5 Mc at *X*-band frequencies over wide environmental conditions. The system dynamically compensates for deviations in frequency due to temperature, vibration, shock, changes in duty cycle, drift with life, and poor voltage regulation. The response time of the AFC system is such that, starting at the limits of the capture range, "on frequency" response is obtained within the first five pulses of the magnetron. One of the radar systems requires a considerable delay between groups of pulses. For this radar, the AFC system provides a memory to hold the conditions for "on frequency" response during the delay periods.

A qualitative analysis of the closed-loop system is made with reference to the Rieke Diagram. It is shown how a single magnetron has been used to meet two different sets of system performance requirements.

System operation and hardware are discussed with reference to practical difficulties.

The Radar Measurement of Range, Velocity and Acceleration—E. J. Kelly (p. 51)

This paper is a study of the ultimate attainable accuracy in the radar measurement of range, range rate, and range acceleration. It is assumed that these quantities are to be measured by a coherent radar with a large output signal-to-noise ratio. The approach is entirely theoretical, and the accuracy evaluated is the accuracy that would be attained with an ideal receiver which performs maximum-likelihood estimates of the unknown parameters. The transmitted waveform is fixed and arbitrary, and the error variances and covariances are evaluated in detail in terms of the amplitude and frequency modulation of the transmitted wave. Specific results are also given for constant amplitude pulses carrying arbitrary combinations of linear and quadratic frequency modulation.

Masers for Radar Systems Applications—H. R. Senf, F. E. Goodwin, J. E. Kiefer, and K. W. Cowans (p. 58)

This paper is intended to provide the systems engineer with a practical introduction to the use of solid-state maser amplifiers in radars. Various environmental problems involved in the successful application of masers are discussed. An elementary survey of reflection-cavity and traveling-wave masers, together with some experimental results are presented. Another section treats the problem of saturation in masers and discusses some of the methods available for protecting masers from the TR leak-through pulses in radar. Progress made in the development of open- and closed-cycle liquid helium cryogenic systems suitable for masers is described. The authors' personal evaluations of the state of the art of ruby masers and closed-cycle helium refrigerators are given in appendixes.

The Electron Beam Parametric Amplifier as a Radar System Component—R. Adler and W. S. Van Slyck (p. 66)

Practical experience is now available with the Electron Beam Parametric Amplifier (EBPA) used as a low-noise preamplifier in radar systems. Principles of operation of the

EBPA are briefly recapitulated. Among its desirable characteristics are unilateral behavior, high stable gain and a double-channel noise figure (NF) of 1 db or less; its bandwidth, input and output impedance remain constant as gain is adjusted. An *L*-band amplifier is described in detail. A discussion of various ways of handling the idler channel follows. The technique of in-pass-band pumping achieves an effective NF of 2.5 db or better in radars with conventional detection. Complications arise with Moving Target Indicator (MTI) systems; remedies are described.

The paper reports on field tests in which these techniques were used, including a few flight tests. The results show substantial improvements in sensitivity and range. They also spotlight the ability of the EBPA to tolerate high overload and to act somewhat like a TR switch.

Design Considerations for Parametric Amplifier Low-Noise Performance—C. R. Boyd, Jr. (p. 72)

The basic characteristics of parametric amplifiers are reviewed briefly, with particular emphasis on the limitations on low-noise performance resulting from diode losses. Normalized curves showing the minimum excess temperature of a parametric amplifier for various spectrum arrangements are presented, where the normalizing factor is the degenerate-mode gain cutoff frequency. Experimental evidence consisting of noise figure measurements on an *X*-band amplifier is used to relate this cutoff frequency to an easily and commonly measured diode quality factor. Design considerations for a hypothetical *L*-band parametric amplifier are discussed to illustrate the implications of the noise analysis.

Steerable Array Radars—Frank C. Ogg, Jr. (p. 80)

The general characteristics of radars using large planar steerable array antennas are discussed. The need for an amplifier for each element is shown, and the tolerances and stability requirements for the amplifiers are discussed. Array geometry, pattern formation and gain, mutual coupling, and beam-steering techniques are summarized. Element minimization and signal-processing techniques are analyzed.

Signal and Data-Processing Antennas—G. O. Young and A. Ksienski (p. 94)

This paper treats the antenna as an information processing device, and applies the concepts of modern information theory to the design of antennas and to the optimization of their performance. The principal optimization criterion employed is maximization of information or data rate.

The general procedure is to treat the antenna as a spatial frequency filter which is being optimized subject to a given set of control inputs. Given these specifications, the information rate is maximized with respect to the antenna system parameters subject to the physical constraints of the system.

It is shown that in a general antenna system where noise is introduced in both the object and image space, the optimum antenna aperture distribution is uniform. When the image, or receiver, noise is zero, the useful output information content and rate are independent of the aperture distribution. An equation relating the signal and noise spectra and the aperture distribution is derived which shows the way in which the signal should be coded so as to maximize the information content. Processing is discussed generally, and a specific nonlinear processing scheme is analyzed. The general conclusion is that nonlinear processing degrades the useful information rate when the SNR is low whereas it may improve the rate at high SNRs. Finally, a number of specific military and space applications of information processing antennas are considered.

Signal Processing Techniques for Surveillance Radar Sets—C. A. Fowler, A. P. Uzzo, Jr., and A. E. Ruvin (p. 103)

One of the major recent advances in radar technology has been in the processing of the received signals. Several techniques have been developed to enhance the desired signals (aircraft) relative to ground clutter, sea clutter, rain, interference from other radars, and active countermeasures.

The following techniques are discussed: MTI, Sweep Integration, and Blanking and Switching. A signal processing system utilizing these techniques is described.

Principles of Pulse Compression—H. O. Ramp and E. R. Wingrove (p. 109)

For good radar system performance, a transmitted waveform is desired that has 1) wide bandwidth for high range resolution and 2) long duration for high velocity resolution and high transmitted energy. In a pulse-compression system, a long pulse of duration T and bandwidth F (product of T and F greater than one) is transmitted. Received echoes are processed to obtain short pulses of duration $1/F$. Compression ratio (the ratio of long-pulse duration to short-pulse duration) is thus the product $T \cdot F$, and is a measure of the combined range and velocity resolution.

Pulse compression occurs if a waveform with a nonlinear phase spectrum is passed through a filter "phase matched" to the waveform. Phase matched means that the nonlinear part of the network phase response is the negative of the nonlinear part of the waveform phase spectrum.

The waveform with rectangular amplitude spectrum and parabolic phase spectrum is ideally suited for pulse compression. Bandwidth and duration can be independently specified, duration-bandwidth products of 100 or more are presently feasible, and the waveform remains phase matched to one filter over a wide range of Doppler frequency shifts.

Airborne Pulse-Doppler Radar—L. P. Goetz and J. D. Albright (p. 116)

Doppler radars are employed for the detection of moving targets whose radar echo area is much smaller than the ground clutter return. Moving targets are separated from clutter on a frequency basis by utilizing the Doppler phenomenon. Continuous-wave Doppler radars have a practical maximum-range capability because the leak-through between the transmitter and receiver causes receiver saturation. This limitation is overcome in pulse-Doppler radar by time-sharing the transmitting and receiving cycles. This paper discusses a typical pulse-Doppler radar and the basic design considerations for the selection of the pulse-recurrence frequency, elimination of clutter, range determination, and oscillator stability requirements.

A High-Resolution Radar Combat-Surveillance System—L. J. Cutrona, W. E. Vivian, E. N. Leith, and G. O. Hall (p. 127)

An account is given of the development of the AN/UPD-1 (XPM-1) system. This airborne mapping radar, by synthesizing an extremely long antenna which expands in length in direct proportion to radar range, provides a linear resolution in the azimuth direction that is constant for all radar ranges.

The Evolution and Application of Coherent Radar Systems—N. R. Gillespie, J. B. Higley, and N. MacKinnon (p. 131)

A brief introduction to coherent radar applications is given by discussing some basic pulse and CW systems. Comments on the historical development of these systems are followed by a general discussion of coherent radar parameter variations as they relate to the accuracy, resolution and ambiguity of target position or speed measurements.

Interferometer Techniques Applied to Radar—E. Gehrels and A. Parsons (p. 139)

A method is described for measuring the angular rate of a radar target by measuring the rate of change of the phase difference between radar echoes received at two widely separated antennas. It is shown that it is possible by the interferometer technique employed to obtain a direct measure of target angular velocity in much the same manner that Doppler measurements yield radial velocities.

Three main questions existed concerning the basic feasibility of such an approach:

1) Will the effect of the fluctuations in time of arrival arising from inhomogeneities in the atmosphere render the data incapable of interpretation?
2) Is sufficient phase stability obtainable in the equipment and in the transmission paths between widely separated sites to permit phase measurements of the required accuracies?
3) Will serious degradations in the data occur as a result of shifts in the phase center of irregularly shaped tumbling objects?

New Techniques in Three-Dimensional Radar—Murray Simpson (p. 146)

The definition and basic equations defining the performance of three-dimensional radar systems are given. In particular the parameters defining data rate for different classes of three-dimensional radar are analyzed. Three-dimensional radars are divided into three classes as follows: single beam-rapid scan systems; multiple beam-scanning systems; and multiple beam-nonscanning systems. Each of these types is defined and compared in terms of important characteristics. It is shown that new developments in electronic scanning and multiple beam antennas have made feasible many of these new three-dimensional radar systems. A number of the more important antennas and their method of utilization in the three-dimensional radar equipment are described. Examples are given of two types of three-dimensional radar that are typical of two classes of this equipment. Finally, some of the more important applications for modern three-dimensional radar equipment are noted.

Recent Advancements in Basic Radar Range Calculation Technique—L. V. Blake (p. 154)

A procedure for radar range calculation is described, reflecting current knowledge of the effects of external natural noise sources, atmospheric-absorption losses, and the refractive effect of the normal atmosphere. The range equation is presented in terms of explicitly defined and readily evaluated quantities. Curves and equations are given for evaluating the quantities that are not ordinarily known by direct measurement. Some conventions are proposed for use in general radar range calculation, including an antenna-noise-temperature curve, minimum-detectable signal-to-noise ratio ("visibility factor") curves, and a formula for the reflection coefficient of a rough sea. A noise-temperature table and a work-sheet for range calculation are included in the Appendix.

Prediction of Coverage for Trans-Horizon HF Radar Systems—G. F. Ross and L. Schwartzman (p. 164)

Coverage patterns for trans-horizon radar systems can be predicted both analytically and empirically. Empirical methods are preferred because of their rapid application and lack of need for elaborate computing facilities. In addition, the coverage techniques introduced may be used eventually to determine the slant range, absorption, and effective noise temperature of trans-horizon radar systems. Some of the fundamental considerations which influence the prediction of coverage, such as geographical location, and the diurnal, seasonal, and anomalous behavior of the ionosphere, are discussed qualitatively. In spite of these factors, however, it is shown how HF radar systems overcome the line-of-sight limitations imposed upon conventional microwave radar systems and theoretically permit up to four or five times the range for a single hop.

A New Display for FM/CW Radars—Herbert H. Naidich (p. 172)

One of the limitations of FM/CW radars, often quoted in the literature, is in their inability to handle multiple targets. Several variations of a comparatively simple Range/Range Rate Display, capable of handling and resolving a large number of targets when used in conjunction with an FM/CW radar, are presented. The FM/CW plane and means for resolving target ambiguities are discussed, as well as system features, which, when used in conjunction with the displays, enable multiple target range and velocity information to be obtained and utilized simultaneously.

Contributors (p. 179)

Product Engineering and Production

Vol. PEP-5, No. 2, June, 1961

Message from the Editor (p. 1)

Call for Papers (p. 2)

Digital Microelectronic Equipment Problems and Potentials—Aaron H. Coleman (p. 3)

Major problems encountered in the design of a micromodule digital computer (MICROPAC) for tactical operation within the Field Army are described and solutions presented. Such problems include module heat transfer, interconnection of modules and module assemblies and selection of module assembly size and configuration.

The utilization of the circuitry booklet configuration for module mounting, interconnection and cooling is described. It is shown that reasonable air cooling will provide adequate heat transfer for several thousand modules dissipating an average of 120 milliwatts per module. The quantitative dependence of over-all circuitry packaging density upon connector pin per module requirements, type of booklet and harness wiring, booklet size and configuration, etc. is presented in analytical form. It is concluded that an over-all circuitry section (including connectors, backplane wiring, etc.) packaging density of 150,000 components per cubic foot is obtainable by the utilization of micromodules with an average packaging density of slightly less than 500,000 components per cubic foot.

The extent to which the equipment designer and user will achieve their objectives by the application of micromodules to military digital equipment is discussed. It is indicated that more than 60,000 modules (each containing such logical elements as a flip-flop, two logic gates or equivalent) can be mounted, interconnected and adequately cooled within a volume occupied by a 6-foot rack. This dramatic reduction of volume (and weight) is accompanied by a corresponding decrease in the equipment support or overhead cost per module.

Philco High Speed Card Reader—N. M. Emslie (p. 13)

This paper describes the mechanical and electrical design and operating characteristics of a high speed tabulating card reader. This unit, a prime input device to the Philco 2000 Computer System, handles, and reads and checks cards at a peak rate of 38 full size tabulating cards per second.

Design problem solutions in the picking and stacking area which make novel use of wrap clutches to provide an indexing card pick and an incremental stacking sensor are described in detail. The characteristics of the photosensitive reading station are also discussed.

Investigation of Production Requirements for Solderless Wire Wrapped Electrical Connections—S. Plasker, A. H. Wenner, and C. A. Selzo (p. 17)

A solderless wire wrapped electrical connection consists of tightly wrapping solid bare wire around a stationary terminal to produce a durable pressure connection.

Properly made, the wrapped connection is a permanent, reliable electrical connection that can be produced faster than soldered connections. The elimination of solder and heat detriments are distinct advantages over the soldered connection. Wire wrapping lends itself to automation, and connections can be easily made on closely spaced terminals. While it is a mechanically strong connection, an individual connection is easily removed, simplifying modification and repair. However, this may be less of an advantage in multi-level wrapping.

The increase in complexity of electronic equipment during the last decade has presented industry with some unique production problems. Not the least of these has been the great increase in the number of electrical connections. The need for speed in making this many connections, without decreasing quality, prompted IBM to expend considerable effort in identifying the variables that affect solderless wire wrapping connections in order to define the controls needed in production. At the present time, these connections are widely used by IBM in both commercial and military applications, and over 100 million solderless wrapped connections were made by IBM in 1960.

The use of the solderless wrapped connection has grown steadily since the Bell System first made the new connection public in 1952. Extensive laboratory tests, performed principally by Bell Laboratories, and field experience have verified the reliability of the connection.

This paper describes the effect of the variables involved in the wire wrapping process which were determined from the results of laboratory tests and manufacturing experience and the process controls required to assure the quality and reliability of production connections.

To meet process requirements consistently, the many variables inherent in the solderless wire wrapping process must be considered. These variables will be discussed under the major variable factors involved in the process.

A Miniature 90×10 Solid State Multiplexer—S. G. Kritzstein and A. V. Ottaviano (p. 29)

The evaluation of a completely solid state electronic multiplexer, with a capacity of 90 channels, is presented. Electrical operation is described as well as mechanical fabrication. A comparison of two types of packaging techniques is made.

Analysis of a Tri-Dimensional Feed Horn Support Structure—Z. M. Slusarek (p. 38)

The design and test analysis of a space structure is presented.

A correlation coefficient, developed from experimental stress analysis and performed on a full scale model under partial loading in the laboratory was used to predict the performance of the structure under actual loading. The results from over 100 tests are shown and discussed.

The Atlas Missile Autopilot—A Case History of PGPEP Principles in Action—John H. Hauser (p. 50)

The approach used in introducing electronic packaging utilizing printed wiring boards in the production design of the ATLAS MISSILE AUTOPILOT is described. An integrated system design approach from circuit schematic to finished product is demonstrated by explanation of design standards adopted and the use of eleven (11) specifications, which covered materials, parts, processes and assembly techniques, as requirement documents on applicable part and assembly drawings.

The role of the specialist as coordinator and integrator of cognizant departmental functions involved in the task is discussed. Printed wiring board parts are used as a specific example to show how Engineering, Purchasing, Processing, Assembly, Inspection, Testing and Quality Assurance tasks are related.

Design Production Coordination for Reducing Lead Time in the AHSR Radar System—Judd Blass, Eugene Arelt, and W. L. Maxson (p. 63)

Thermal Design Solutions for Micro-Modular Equipment—Gerard Rezek and Paul K. Taylor (p. 71)

The Product Engineer and the Magnetic Thin Film—P. Kuttner (p. 85)

Magnetic thin films have great potential as memory elements in digital computers. The properties of thin films are such that memories can be operated at speeds of the order of 100 nanoseconds or less, non-destructively in certain instances. While the elements themselves show great promise, there are many problems attendant to their use, the solution of which must come from experts in packaging techniques.

Value Engineering and Product Engineering—Carlos Fallon (p. 93)

Value Engineering is coming of age. In the hands of experienced product engineers it can grow into a truly professional tool for improving the competitive position of a company. It applies the precise techniques of science and engineering to those areas of evaluation, programming, and decision-making which have heretofore been governed by intuition. In estimating, bidding, and scheduling, Value Engineering saves not only money but also elapsed time. In design, development and production, it seeks the best ratio between desirable qualities and their cost in available resources.

This paper will illustrate how Value Engineering can be utilized within the conventional engineering disciplines to provide the quantitative data necessary for better balanced specifications, for reducing areas of uncertainty in product planning, and for better decisions in both product design and program management.

Epoxy Resin Molds for Encapsulating Electronic Circuitry into Modules—John J. Tallent (p. 98)

This paper discusses the various procedures, methods and recommendations involving the encapsulation of electronic modules utilizing conventional components. In addition this streamlined approach provides Engineering and Manufacturing a means to produce molds easily and economically, as well as a tool, which offers fabrication flexibility.

Development of a Thermally Conductive Ceramic Component Board—Gerald H. Kriss and Louis J. Polaski (p. 104)

This paper describes the development and evaluation of a ceramic component board having all circuit connections electrically insulated but thermally grounded.

Individual circuits are encapsulated in epoxy parallelopipeds having large diameter leads of nickel clad copper wire. The leads in turn are resistance welded to metallic (Kovar) studs which have been brazed into an inorganic (Beryllium Oxide Ceramic) wafer having exceedingly good thermal conductance.

Interconnections between weld studs are accomplished by metalized plated runs.

The component board assembly was then evaluated under simulated operating conditions, *i.e.*, edge clamped to an infinite heat sink and in a vacuum environment. Internal heat rise within the circuit modules was monitored and compared to that found in another module which had not been welded to the board, and plots of the thermal gradients across the ceramic wafer were made.

Sub-Modular Packaging of Airborne Electronic Systems—John F. Dalton (p. 112)

A packaging concept has been developed to meet the flexible requirements demanded when producing systems for both large and small production runs of airborne electronic systems.

Multilayer Etched Laminates: A New Packaging Design Tool—Norman Schuster and William Reimann (p. 114)

High Density Electronic Packaging Via Welded Honeycomb Structures (Abstract)—Charles W. Johnson (p. 128)

Contributors (p. 129)

Abstracts and References

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NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

Acoustics and Audio Frequencies 1358
Antennas and Transmission Lines 1358
Automatic Computers 1359
Circuits and Circuit Elements 1359
General Physics 1361
Geophysical and Extraterrestrial Phenomena 1362
Location and Aids to Navigation 1364
Materials and Subsidiary Techniques .. 1364
Mathematics 1368
Measurements and Test Gear 1368
Other Applications of Radio and Electronics 1368
Propagation of Waves 1368
Reception 1369
Stations and Communication Systems .. 1369
Subsidiary Apparatus 1370
Television and Phototelegraphy 1370
Tubes and Thermionics 1371
Miscellaneous 1372

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

UDC NUMBERS

Certain changes and extensions in UDC numbers, as published in PE Notes up to and including PE 666, will be introduced in this and subsequent issues. The main changes are:

Artificial satellites:	551.507.362.2	(PE 657)
Semiconductor devices:	621.382	(PE 657)
Velocity-control tubes, klystrons, etc.:	621.385.6	(PE 634)
Quality of received signal, propagation conditions, etc.:	621.391.8	(PE 651)
Color television:	621.397.132	(PE 650)

The "Extensions and Corrections to the UDC," Ser. 3, No. 6, August, 1959, contains details of PE Notes 598–658. This and other UDC publications, including individual PE Notes, are obtainable from The International Federation for Documentation, Willem Witsenplein 6, The Hague, Netherlands, or from The British Standards Institution, 2 Park Street, London, W. 1, England.

ACOUSTICS AND AUDIO FREQUENCIES

534.213.4 **2063**

On the Transmission of Acoustic Waves through a Circular Channel of a Thick Wall—Y. Nomura and S. Inawashiro. (*Sci. Repts. Res. Inst. Tohoku Univ., Ser. B*, vol. 12, no. 1, pp. 57–71; 1960.)

A list of organizations which have available English translations of Russian journals in the electronics and allied fields appears each June and December at the end of the Abstracts and References section.

The Index to the Abstracts and References published in the PROC. IRE from February, 1959 through January, 1960 is published by the PROC. IRE, June, 1960, Part II. It is also published by *Electronic Technology* (incorporating *Wireless Engineer* and *Electronic and Radio Engineer*) and included in the March, 1961 issue of that Journal. Included with the Index is a selected list of journals scanned for abstracting with publishers' addresses.

534.232–14:534.6.089.6 **2064**

Sonar Transducer Pulse Calibration System—J. D. Wallace and E. W. McMorrow. (*J. Acoust. Soc. Am.*, vol. 33, pp. 75–84; January, 1961.) The development of equipment and techniques for making measurements on underwater transducers is described.

534.283–8:537.312.62 **2065**

Ultrasonic Attenuation in Superconductors—T. Tsuneto. (*Phys. Rev.*, vol. 121, pp. 402–415; January, 1961.) A general treatment of ultrasonic attenuation of both longitudinal and transverse waves in superconductors is given on the basis of the Bardeen-Cooper-Schrieffer theory.

534.441.2 **2066**

An Acoustic Spectrum Analyser with Electronic Scanning—D. J. H. Admiraal. (*Philips Tech. Rev.*, vol. 21, pp. 349–356; October, 1960.) Improvements have been made to earlier equipment [*ibid.*, vol. 7, pp. 50–58; 1942 (Beljers)] by using semiconductor diodes and transistors.

534.614–8:621.3.018.75 **2067**

Pulse Superposition Method for Measuring Ultrasonic Wave Velocities in Solids—H. J. McSkimin. (*J. Acoust. Soc. Am.*, vol. 33, pp. 12–16; January, 1961.) Details are given of a pulse superposition technique which takes into account the coupling effect when a quartz transducer is cemented to the specimen.

534.8 **2068**

Some Periodic Variations in Low-Frequency Acoustic Ambient Noise Levels in the Ocean—G. M. Wenz. (*J. Acoust. Soc. Am.*, vol. 33, pp. 64–74; January, 1961.)

534.84 **2069**

New Distortion Criterion—E. R. Wigan. (*Electronic Tech.*, vol. 38, pp. 128–137 and 163–174; April and May, 1961.) A formula, described as the "distortion criterion," is derived from the results of an analysis of audience reaction to nonlinear distortion.

534.84 **2070**

The Damping of 'Eigentones' in Small Rooms by Helmholtz Resonators—F. J. van Leeuwen. (*E.B.U. Rev.*, pp. 155–161; August, 1960.) The natural oscillation or "boom" of small rooms is considered theoretically. Damping of this effect can be achieved by means of small Helmholtz resonators. A design formula is given for these resonators, and suggestions are made regarding installation.

534.844.1+621.317.2:538.566.08 **2071**

Reverberation Chamber Technique and Construction of a Large Reverberation Chamber for Electromagnetic Waves—Meyer, Helberg, and Vogel. (See 2325.)

621.395.623.7.001.4 **2072**

Performance Tests on Loudspeakers—M. T. Haitjema, W. Kopinga, and S. J. Porte. (*Philips Tech. Rev.*, vol. 21, pp. 362–372; October, 1960.) Sound pressure, electrical impedance and efficiency are measured as a function of frequency. Methods of determining transient response, resonance frequency and directivity are given.

ANTENNAS AND TRANSMISSION LINES

621.372.2 **2073**

The Helix as a Transmission Line for Waveguide Modes—G. Piefke. (*Nachrtech. Z.*, vol. 13, pp. 335–341; July, 1960.) Results of earlier work (*e.g.*, 2459 of 1949) are summarized and discussed treating the helical line as a waveguide in any external medium and taking account of the finite wire thickness.

621.372.2:537.312.62 **2074**

Field Solution for a Thin-Film Superconducting Strip Transmission Line—J. C. Swihart. (*J. Appl. Phys.*, vol. 32, pp. 461–469; March, 1961.) A sinusoidal wave solution is found for a superconducting transmission line. This solution gives a slow mode of propagation. At low temperatures and frequencies where losses are low, the velocity is dispersionless. The solutions are continuous through the critical temperature. A lumped-circuit interpretation is given.

621.372.2:621.319.74 **2075**

The External Electromagnetic Fields of Shielded Transmission Lines—J. D. Meindl and E. R. Schatz. (PROC. IRE, vol. 49, p. 816; April, 1961.)

621.372.2:621.372.44:621.375.9 **2076**

Interpretation of the Transmission-Line Parameters with a Negative-Conductance Load and Application to Negative-Conductance Amplifiers—C. T. Stelzried. (PROC. IRE, vol. 49, pp. 812–813; April, 1961.) Expressions are given for the reflection coefficient, power available and standing-wave ratio.

621.372.2:621.372.51 **2077**

Note on a Balun: Solution by a Tapered Potential—C. C. Eaglesfield. (PROC. IRE, vol. 49, pp. 810–811; April, 1961.) The intuitive design of Duncan and Minerva (1489 of 1960) has been replaced by a design depending on an analytic approach.

621.372.8.049.7 2078

Waveguide Components—a Survey of Methods of Manufacture and Inspection—D. J. Doughty. (*J. Brit. IRE*, vol. 21, pp. 169–189; February, 1961). 59 references.

621.372.81 2079

Theory of Waveguides and Cavities: Part 3—Perturbation Theory and Its Applications—R. A. Waldron. (*Electronic Tech.*, vol. 38, pp. 178–183; May, 1961). Two applications are considered: a) the use of a cavity to measure the dielectric constant of a solid, and b) the attenuation in a waveguide due to the dielectric loss. Part 2: 1723 of June.

621.372.823 2080

Effect of a Radial Discontinuity in a Circular Waveguide on the Propagation of a TE$_{01}$ Wave—M. Jouguet. [*Câbles & Trans. (Paris)*, vol. 14, pp. 270–274; October, 1960.] The relative amplitudes of various TE$_{0n}$-type parasitic waves ($n \geq 2$) introduced by the discontinuity are determined.

621.372.823 2081

Mode Conversion in Metallic and Helix Waveguide—H. G. Unger. (*Bell Sys. Tech. J.*, vol. 40, pp. 613–626; March, 1961.) Mathematical solutions are given for mode conversion and transmission losses due to mechanical imperfections.

621.372.823 2082

Winding Tolerances in Helix Waveguide—H. G. Unger. (*Bell Sys. Tech. J.*, vol. 40, pp. 627–643; March, 1961. Various causes of losses in circular electric waves are considered. The most significant loss is shown to be due to an irregular tilt of the winding, for which an expression is derived.

621.372.823:621.372.83 2083

Reflections and Mode Conversions in Imperfect Junctions of TE$_{01}$-Wave Transmission Line—K. Noda. (*Rev. Elec. Commun. Lab., Japan*, vol. 8, pp. 549–559; November/December, 1960.) The effects of tilt and offset between the waveguide axes, and of an elliptical cross section in one waveguide are calculated.

621.372.823:621.372.852.23 2084

The H$_{on}$ Mode in Circular Waveguide with Equidistant and Coaxially Arranged Band-Shaped Rings of Perfect Conductivity—H. Buchholz. (*Arch. Elektrotech.*, vol. 45, pp. 249–264; July, 1960.) The effect of a periodic structure consisting of thin narrow rings inside a perfectly conducting waveguide is investigated. An approximate solution is derived for the phase shift along this system.

621.372.826+621.391.814:537.56 2085

Propagation of Electromagnetic Waves along a Thin Plasma Sheet—Wait. (See 2352.)

621.372.826+621.391.814.029.64 2086

TE Surface Waves Guided by a Dielectric-Covered Metal Plane—Morris and Mungall. (See 2353.)

621.372.829:621.396.677.7 2087

Electromechanically Scanned Trough Waveguide Array—W. Rotman and A. Maestri. (*Electronics*, vol. 34, pp. 54–57; March, 1961.) An asymmetrical obstacle introduced into a trough waveguide changes transmission from a nonradiating to a radiating mode.

621.372.852.323 2088

Theoretical Study of Nonreciprocal Resonant Isolators—J. B. Davies. (*Philips Res. Repts.*, vol. 15, pp. 401–432; October, 1960.) The attenuation in each direction is calculated as a function of frequency for various ferrite shapes within rectangular waveguide propagating the dominant TE mode. Perturbation theory is used and the results are valid only for small volumes of ferrite.

621.396.67.012.12:621.317.3 2089

Measurements on Transmitter Aerials of the Austrian Broadcasting Service with the aid of a Helicopter—E. Kohlgruber. (*Radioschau*, vol. 10, pp. 248–250; July, 1960.) A brief description is given of the procedure and technical equipment used for the measurement of horizontal and vertical radiation diagrams of broadcast and television transmitter antennas.

621.396.673.011.21 2090

Impedance of a Monopole Antenna with a Circular Conducting-Disk Ground System on the Surface of a Lossy Half-Space—S. W. Maley and R. J. King. (*J. Res. NBS*, vol. 65D, pp. 183–188; March and April, 1961.) The base impedance of a $\lambda/4$ monopole is calculated by three different methods, and measured experimentally at 3 cm λ using a water-filled tank.

621.396.677:523.164 2091

The Radio Telescope for 7.9 Metres Wavelength at the Mullard Observatory—Costain and Smith. (See 2177.)

621.396.677.029.45/.51 2092

Some Preliminary Experimental Tests of a Novel Method of Radiating at Very Low Frequencies—R. N. Gould. (*Nature*, vol. 190, pp. 332–333; April, 1961.) Experiments have been conducted in Scotland to assess the suitability of a long narrow strip of land as a radiator and to determine its characteristics. 3000 yards of cable were laid across the base of a peninsula 10 miles long, each end of the cable being earthed in the sea, and the transmitter output of 50 w at 10 kc was applied to the midpoint. Preliminary results demonstrate the feasibility of the proposals, though measurements were marred by capacitance effects between the cable and earth.

621.396.677.3 2093

Equivalence between Continuous and Discrete Radiating Arrays—A. Ksienski. (*Canad. J. Phys.*, vol. 39, pp. 335–349; February, 1961.) The agreement between the radiation patterns of arrays of sources and those of continuously illuminated apertures is shown to be close. The effect of varying element spacing is found.

621.396.677.3 2094

Two-Element Aerial Array—V. G. Welsby. (*Electronic Tech.*, vol. 38, pp. 160–163; May, 1961.) A two-element multiplicative system is described in which signal waveforms composed of a number of sinusoidal components are used to obtain a directional pattern comparable with that of a multi-element additive array. The principle may be applied to give a simplified electronic beam-scanning system.

621.396.677.3.012.12:681.142 2095

An Analogue Computer for Aerial Radiation Patterns—H. Page, G. J. Phillips, and J. A. S. Fox. (*E.B.U.* **Rev.**, no. 62A, pp. 146–149; August, 1960. *Electronic Engrg.*, vol. 33, pp. 206–212; April, 1961.) A detailed description is given of a computer for determining the horizontal radiation patterns of arrays consisting of identical elements. The currents in the elements may have any desired amplitude and phase. See also 2235 of 1960 (Mitchell).

621.396.677.4 2096

Plane Aerial with Periodically Bent Conductor—G. V. Trentini. (*Frequenz*, vol. 14, pp. 239–243; July, 1960.) A directional antenna is investigated which consists of a conductor bent periodically in one plane arranged in parallel with a sheet reflector at a spacing of about $\lambda/10$. Narrow-beam radiation can be achieved, the direction of the main beam depending on frequency. Several arrangements, including a four-antenna array for omnidirectional radiation, are discussed.

621.396.677.8 2097

Fresnel Region Fields of Circular Aperture Antennas—M. K. Hu. (*J. Res. NBS*, vol. 65D, pp. 137–147; March and April, 1961.) An analysis is given, with numerical results, for antennas with nonuniform illumination.

621.396.677.8 2098

Transient Behaviour of Aperture Antennas—B. R. Mayo and C. Polk. (PROC. IRE, vol. 49, pp. 817–819; April, 1961.) Corrections to 3373 of 1960 are given, together with additional conclusions.

621.396.677.85:621.396.965 2099

A High-Speed Scanning Radar Antenna—F. Valster. (*Philips Tech. Rev.*, vol. 22, pp. 29–35; November, 1960.) A description is given of an experimental installation using a Luneberg-lens scanning system at speeds up to 10 rps. At these speeds the observation of fast-moving objects is greatly improved.

AUTOMATIC COMPUTERS

681.142 2100

A Versatile Forcing-Function Generator—J. Morrison. (*Electronic Engrg.*, vol. 33, pp. 155–159; March, 1961.) An electronic generator for use with analog computers, which produces sine, square, triangular, ramp, step or impulse functions over the range 0.001–100 cps to an accuracy within $\frac{1}{4}$ per cent is given.

681.142:517.512.2 2101

A Successful Version of the Beevers-Macewan Fourier Synthesizer using Dekatron Counters—J. W. Jeffery. (*J. Sci. Instr.*, vol. 38, pp. 119–125; April, 1961.) A Fourier synthesizer is described which allows a possible 100 harmonics to be specified with amplitudes ranging from 1–100 units. Both positive and negative harmonic components are acceptable. See 248 of 1943 (Macewan and Beevers).

681.142:537.226 2102

A Dielectric Drum Storage System—S. Morleigh. (*J. Brit. IRE*, vol. 21, pp. 211–219; March, 1961.) The basic theory of a dynamic electrostatic storage system is given. Experimental results with a ceramic drum are given; packing densities of 40 bits per inch were obtained with SNR's of 12:1.

681.142:538.221:539.23 2103

Designing Thin Magnetic Film Memories for High Speed Computers—E. E. Bittmann. (*Electronics*, vol. 34, pp. 39–41; March, 1961.) A storage system has been built which will store 320 words each of 8 bits and which has a cycle time of 0.2 μsec.

681.142:621.374.33 2104

Current-Operated Diode Logic Gates—H. Reinecke, Jr. (*Commun. and Electronics*, pp. 762–772; January, 1961.) The basic logic circuits are described and practical examples are given.

681.142:621.396.677.3.012.12 2105

An Analogue Computer for Aerial Radiation Patterns—Page, Phillips, and Fox. (See 2095.)

CIRCUITS AND CIRCUIT ELEMENTS

621.318.57:621.372.44:539.23 2106

Stable-Oscillation Conditions for the Magnetic-Film Parametron—R. M. Sanders. (*J. Appl. Phys.*, vol. 32, pp. 478–482; March, 1961.) A mathematical analysis of a parametron is given. This parametron uses a single-domain magnetic film as the core of a nonlinear inductor absorbing energy from an alternating pump field and delivering energy to a signal winding. Graphical means of determining stability conditions, amplitudes and phases of the oscillating variables, and the range of operating frequencies are discussed.

621.318.57:621.382.23:621.372.44 2107

Microwave Bistable Circuits using Varactor Diodes—C. L. Heizman. (Proc. IRE, vol. 49, pp. 829–830; April, 1961.) Using a 10-Gc carrier frequency, switching speed between states was less than 10 nsec. A threshold logic circuit with power gain is illustrated.

621.318.57:621.382.3:621.376 2108

Symmetrical Transistors as A.C. or D.C. Switches and their Applications in Modulator and Demodulator Circuits—J. F. O. Evans, D. A. Gill, and B. R. Moffitt. (*J. Brit. IRE*, vol. 21, pp. 143–149; February, 1961.)

621.319.45 2109

An Investigation of Columbium as an Electrolytic Capacitor Metal—A. Shtasel and H. T. Knight. (*J. Electrochem. Soc.*, vol. 108, pp. 343–347; April, 1961.) The characteristics of capacitors prepared from Cb are very similar to those of Ta, except that the working voltages are about one third and the dc leakage currents about double that of similar Ta capacitors.

621.372.4 2110

Extension of a Theorem for Normal Passive Electrical Two-Poles in the Steady State—L. Lunelli. (*Alta Frequenza*, vol. 29, pp. 377–388; June-August, 1960.) The theorem of R. M. Cohn (*Proc. Am. Math. Soc.*, vol. 1, pp. 316–324; June, 1950) which gives the terminal resistance of a two-pole network as a function of the resistances of its elements, is extended to allow for *n* degrees of freedom of the network satisfying the reciprocity condition.

621.372.4/.5:681.142 2111

The Representation of Coupling-Free Branched Circuits on an Analogue Computer—W. Schüssler. (*Arch. elekt. Übertragung*, vol. 14, pp. 327–334; August, 1960.) A method is given for simulating branched circuits on an analog computer so that each circuit component can be varied independently to determine its effect on circuit characteristics. See also 3737 of 1960.

621.372.4:681.142 2112

Realization of Second-Order Two-Pole Functions with Transformerless Canonical Circuits by means of Program-Controlled Computers—R. Unbehauen. (*Nachrtech. Z.*, vol. 13, pp. 321–326; July, 1960.)

621.372.413:621.318.134 2113

The Size Effect of Ferrite Spheres—W. Hauser and L. Brown. (*Quart. J. Mech. Appl. Math.*, vol. 13, pt. 3, pp. 257–271; August, 1960.) The integral-equation technique is used to derive an approximate formula for the apparent susceptibility of a small ferrite sphere within a microwave cavity. Using a variational principle a first-order estimate is obtained for the effect of a plane wall and the effect of the size of the sphere. See 27 of 1960.

621.372.5 2114

Calculation of the Transfer Function from the Magnitude of the Transmission Factor—G. Wunsch. (*Frequenz*, vol. 14, pp. 244–247; July, 1960.) A generalization and modification of Küpfmüller's system theory to eliminate certain contradictions with practical systems is given.

621.372.5 2115

The Matrix of a Recurrent Network of Equal Quadripoles (Representation of Any Power of a Matrix)—G. Doetsch. (*Arch. elekt. Übertragung*, vol. 14, pp. 335–340; August, 1960.) An explicit expression is derived for the *n*th power of a matrix representing *n* equal four-terminal networks in cascade.

621.372.54 2116

Synthesis of Electrical Filters from Operating Parameters by Means of Zolotarëv Fractions—A. F. Ufel'man. [*Radiotekhnika* (*Moscow*), vol. 15, pp. 64–72; May, 1960.] Design formulas are given in which special functions are avoided by using mathematical tables of Glowatzki (see 2051 of 1957) and which involve less calculation than is required using the Grossman formulas (2053 of 1957).

621.372.54 2117

Electrical Wave Filter with Prescribed Operating Characteristics—J. B. Fischer. (*Arch. elekt. Übertragung*, vol. 14, pp. 283–298; July, 1960.) Calculations are simplified by the application of image-parameter theory to filter design, which may outweigh the advantages of economy in circuit components resulting from the use of insertion-loss methods. Exact relations are derived between the quadripole and insertion-loss characteristics of reactance quadripoles, and examples are given.

621.372.54 2118

Gaussian-Response Filter Design—M. Dishal. (*Elec. Commun.*, vol. 36, pp. 3–26; 1959.) Exact data are given for the design of both low- and band-pass filters having characteristics which are *n*th-order approximations to the perfect Gaussian amplitude response, *n* being the number of elements in the complete filter.

621.372.54 2119

General Low-Pass and High-Pass Antimetric Filters Inserted between Equal Resistances—J. E. Colin. [*Câbles & Trans.* (*Paris*), vol. 14, pp. 262–269; October, 1960.]

621.372.54:681.142 2120

The Application of Electronic Digital Computers in Network Theory—H. Härtl. (*Nachrtech. Z.*, vol. 13, pp. 313–316; July, 1960.) The applications discussed are a) the synthesis of a quadripole reactance filter, and b) network analysis.

621.372.54+621.372.57].029.42 2121

Filter Circuits for Extremely Low Frequencies without the Use of Inductances—H. G. Jungmeister and H. L. König. (*Arch. elekt. Übertragung*, vol. 14, pp. 317–324; July, 1960.) Filter-design procedure using double-T RC networks is described. Passive and active filter circuits are given.

621.372.543.2:534.143 2122

Electromechanical Quadripoles as Coupling Filters—E. Trzeba. (*Hochfrequenz. und Elektroak.*, vol. 69, pp. 108–117; June, 1960.) The equivalent circuits of mechanical resonators and electromechanical transducers are derived and the design of band-pass filters consisting of input and output electromechanical transducers coupled by a mechanical transmission line is described.

621.372.543.2:621.372.412 2123

Ceramic I.F. Transformers—R. C. V. Macario. (*Wireless World*, vol. 67, pp. 253–256; May, 1961.) The principles of design of the radial-mode resonator as used in IF circuits is discussed See 2124.

621.372.543.2:621.372.412 2124

Design Data for Band-Pass Ladder Filters employing Ceramic Resonators—R. C. V. Macario. (*Electronic Engrg.*, vol. 33, pp. 171–177; March, 1961.) Graphical and tabulated design data based on image-parameter theory are given for filters comprising piezoelectric disks resonating in a radial mode with or without capacitors. The ranges of center frequency, bandwidth and image impedance achievable are discussed.

621.373.029.6:621.372.44 2125

An Analysis of the Magnetic Second-Subharmonic Oscillator—A. Lavi and L. A. Finzi. (Proc. IRE, vol. 49, pp. 779–787; April, 1961.) The analysis refers to a parametric oscillator with two ferromagnetic cores. The steady-state operation with both current and voltage pump drives is studied to determine the values of the circuit parameters which will give subharmonic oscillations. The experimental waveforms are close to those predicted.

621.373.42:621.372.44 2126

Oscillator Circuits with Variable Parameters (Rheolinear Oscillators)—E. G. Woschni. (*Hochfrequenz. und Elektroak.*, vol. 69, pp. 103–108; June, 1960.) Approximation formulas are given for determining pull-in range and gain of parametric oscillators; sinusoidal variation of capacitance and of attenuation are the cases particularly considered. See also 3560 of 1956.

621.373.42.029.55:621.396.933 2127

An Airborne Frequency Generating Unit for the H.F. Communication Band—T. F. Hargreaves, J. H. Gifford, and G. E. Smythe. (*J. Brit. IRE*, vol. 21, pp. 129–136; February, 1961.) The unit gives an output frequency, with channel spacing of 1 kc, in the band 3.5–26.5 Mc. A variable oscillator is phase-locked to a frequency derived from a 5-Mc standard.

621.373.421.13 2128

Piezoelectric Excitation of Quartz Oscillators Operating in the Thickness Mode by means of a Parallel Field—R. Bechmann. (*Arch. elekt. Übertragung*, vol. 14, pp. 361–365; August, 1960.) The parallel-field excitation of AT- and BT-cut crystals is considered and its advantages are discussed. Equivalent circuits are given of two experimental oscillators, for 750 kc and 1 Mc using AT-cut quartz crystal resonators. See also 3544 of 1960.

621.373.431.1 2129

Frequency Control and Frequency Fluctuations of the Astable Multivibrator—G. Linckelmann. (*Arch. elekt. Übertragung*, vol. 14, pp. 299–313; July, 1960.) A modified multivibrator circuit is given which permits frequency variation over the range 1:400 by means of grid bias control. The causes of fluctuations of pulse repetition frequency are investigated and design formulas are derived for minimizing these effects.

621.373.52 2130

High-Frequency Transistor Polyphase Oscillator—T. Takagi and K. Mano. (*Sci. Repts. Res. Inst. Tohoku Univ., Ser. B*, vol. 12, no. 1, pp. 27–39; 1960.) Conditions for oscillation of a polyphase transistor oscillator are developed from its tube equivalent (791 of March). Experimental results show the relative performances of single, polyphase, and push-pull transistor oscillators and demonstrate the superiority of the polyphase oscillator when a high power output is required at high frequencies.

621.374.4:621.372.8 2131

Waveguide Harmonic Generators—J. Brown. (Proc. IRE, vol. 49, p. 825; April, 1961.) The generator suggested by Hedderly (4144 of 1960) is regarded as a multiphase rectifier circuit.

621.374.4:621.396.62 2132

The Synthesis of High-Purity Oscillations Suitable for Single Sideband Receivers—P. S. Carnt and E. Ribchester. (*J. Brit. IRE*, vol. 21, pp. 237–240; March, 1961.) A phase-locked oscillator has its output mixed with part of a 100-kc spectrum to form an IF in the region

900–1000 kc. An interpolating signal with unwanted components 40 db down is used to lock the loop. Frequencies at 1-kc intervals between 3 and 30 Mc are derived.

621.374.4.029.65 2133

Harmonic Generators for the 40000-Mc/s Band—L. Grifone. (*Ricerca Sci.*, vol. 30, pp. 1214–1220; August, 1960.) A description of two signal generators covering the ranges 31–41 and 39–51 Gc is given. They incorporate a 9-Gc klystron oscillator and Si-diode frequency multipliers (665 of 1955.)

621.375.221 2134

Increase of the Gain of a Wide-Band Distributed Amplifier by Compensation of its Zeroes and by Arrangement of the Residual Poles in a Tchebycheff Ellipse—J. Koch. (*Arch. elekt. Übertragung*, vol. 14, pp. 348–360; August, 1960.) A set of equations is obtained for a two-tube distributed amplifier, and its component values and characteristics are calculated for a limiting frequency of 300 Mc. General formulas for distributed amplifiers with any number of tubes are derived. Theoretical results are verified with the aid of an experimental two-tube circuit. The Tchebycheff-type amplifier is shown to have a gain greater, by a factor of 1.84, than the conventional distributed amplifier.

621.375.4 2135

Bandpass Transistor Amplifiers—C. J. McCluskey. (*Electronic Tech.*, vol. 38, pp. 183–187; May, 1961.) A determinant method is given for the analysis of amplitude and phase responses of tuned amplifiers having complex internal feedback circuits.

621.375.9:621.372.44 2136

A Wide-Band Single-Diode Parametric Amplifier using Filter Techniques—A. G. Little. (PROC. IRE, vol. 49, pp. 821–822; April, 1961.) An arrangement is described using parallel-tuned circuits at appropriate points along the signal line to give bandwidths up to 130 Mc at a center frequency of 3.3 Gc.

621.375.9:621.372.44 2137

A Nondegenerate *S*-Band Parametric Amplifier with Wide Bandwidth—G. Schaffner and F. Voorhaar. (PROC. IRE, vol. 49, pp. 824–825; April, 1961.) Band-pass filters in the input and idler circuits are used to give a bandwidth of 80 Mc at a center frequency of 2.5 Gc. Operation in four different modes is possible.

621.375.9:621.372.44 2138

A Nearly Optimum Wide-Band Degenerate Parametric Amplifier—M. Gilden and G. L. Matthaei. (PROC. IRE, vol. 49, pp. 833–834; April, 1961.) A double-resonator single-diode design with 3-db bandwidth of 210 Mc centered on 1 Gc is given.

621.375.9:621.372.44:621.372.2 2139

Interpretation of the Transmission-Line Parameters with a Negative-Conductance Load and Application to Negative-Conductance Amplifiers—Stelzried. (See 2076.)

621.375.9:621.372.44:621.385.6 2140

Behavior of Thermal Noise and Beam Noise in a Quadrupole Amplifier—R. Adler and G. Wade. (PROC. IRE, vol. 49, p. 802; April, 1961.)

621.375.9:621.382.23 2141

A Broad-Band Tunnel-Diode Amplifier—N. F. Moody and A. G. Wacker. (PROC. IRE, vol. 49, p. 835; April, 1961.) A first-order theory for an amplifier using tunnel diodes is presented. The series resistance and inductance of the diodes is neglected except where stability is concerned. The amplifier could be built using strip or coaxial lines.

621.376.223 2142

Elimination of Even-Order Modulation in Rectifier Modulators—D. G. Tucker. (*J. Brit. IRE*, vol. 21, pp. 161–167; February, 1961.) The time-varying-resistance function of the modulator is considered not to be a square wave but to contain even-order carrier harmonics.

621.376.223 2143

The Relative Magnitude of Modulation Products in Rectifier Modulators and some Effects of Feedback—D. P. Howson. (*J. Brit. IRE*, vol. 21, pp. 275–281; March, 1961.) The various modulation products occurring in series, shunt and ring modulators are evaluated for square-wave switching of the rectifiers assuming that the terminations are resistive. The information is used in the design of feedback modulators.

621.376.33 2144

The Round-Travis Discriminator—K. R. Sturley. (*Electronic Tech.*, vol. 38, pp. 186–189; May, 1961.) A re-examination of Johnstone's analysis of the Round-Travis amplitude discriminator (1220 of 1957) shows that the conditions indicated are not those giving minimum distortion; a correction is proposed.

GENERAL PHYSICS

530.162:621.391.822 2145

Thermal Noise in Dissipative Media—H. A. Haus. (*J. Appl. Phys.*, vol. 32, pp. 493–500; March, 1961.) To account for the spontaneous thermal fluctuations in a general dissipative medium, a current-source term is introduced into Maxwell's equations. The results are applicable to nonuniform media and to media at nonuniform temperatures.

537.311.33 2146

Theory of Electron-Phonon Interactions—G. D. Whitfield. (*Phys. Rev.*, vol. 121, pp. 720–734; February, 1961.) "The theory of the interaction of electrons and acoustic phonons in nonpolar crystals has been formulated in terms of a new set of basis states, whose wave functions are essentially Bloch functions that deform with the lattice. The major part of the interaction may then be calculated in terms of the strain tensor rather than the displacement of the lattice. A result of the theory is a generalization of the deformation potential theorem."

537.525.72:538.569 2147

A Gas Discharge Free in Space, Glowing at the Focus of a Radar Paraboloid—J. Geerk and H. Kleinwächter. (*Z. Phys.*, vol. 159, pp. 378–383; August, 1960.) An electrodeless gas discharge in a low-pressure vessel was achieved using an arrangement of two paraboloidal mirrors and coherent EM radiation at 3 cm λ.

537.529:537.311 2148

On the Relation between Zener Breakdown and Residual Resistance in Crystals—P. Gosar. (*Nuovo Cim.*, vol. 18, pp. 241–250; October, 1960. In English.) The theory of Zener breakdown in crystals is extended to the case of very strong electric fields.

537.533.8 2149

Energy Dissipation and Secondary Electron Emission in Solids—H. Kanter. (*Phys. Rev.*, vol. 121, pp. 677–681; February, 1961.) Experiments show a proportionality between secondary-electron yield and energy dissipation by incident electrons.

537.533.8 2150

Contribution of Back-Scattered Electrons to Secondary-Electron Formation—H. Kanter. (*Phys. Rev.*, vol. 121, pp. 681–684; February, 1961.) The contribution observed was large even in materials of low Z; it was 40 per cent in Al for 10-kev electrons.

537.56 2151

Pulse Conduction in Decaying Plasma—V. Arunasalam and J. D. Trimmer. (*Rev. Sci. Instr.*, vol. 32, pp. 282–285; March, 1961.) Apparatus has been constructed in which plasma, ionized by 144-Mc RF excitation, is subjected to repeated submicrosecond voltage pulses immediately after excitation is removed; the current is measured.

537.56 2152

Generation and Measurement of Highly Ionized Quiescent Plasmas in Steady State—R. C. Knechtli and J. Y. Wada. (*Phys. Rev. Lett.*, vol. 6, pp. 215–217; March, 1961.) A simple generation technique is described. Experimental results validate double-probe measurements, indicate purely ambipolar diffusion in homogeneous dc magnetic fields and give a recombination coefficient of Cs plasmas below 10^{-10} cm^3 sec^{-1}.

537.56 2153

Drift Velocities of Slow Electrons in Helium, Neon, Argon, Hydrogen and Nitrogen—J. L. Pack and A. V. Phelps. (*Phys. Rev.*, vol. 121, pp. 798–806; February, 1961.)

537.56:537.533 2154

Electromagnetic Interaction of a Beam of Charged Particles with Plasma—J. Neufeld and P. H. Doyle. (*Phys. Rev.*, vol. 121, pp. 645–658; February, 1961.) The theory of growing plasma waves is generalized to include waves propagated in directions other than the beam direction.

537.56:538.566 2155

A Method for Measuring High Electron Densities in Plasmas—S. Takeda and M. Roux. (*J. Phys. Soc. Japan*, vol. 16, pp. 95–98; January, 1961.) It is proposed that the standing-wave pattern produced by plane microwaves at the plasma boundary be measured to give the complex reflection coefficient which is related to the electron density and collision frequency.

537.56:538.63 2156

Diffusion of Plasma across a Magnetic Field—J. B. Taylor. (*Phys. Rev. Lett.*, vol. 6, pp. 262–263; March, 1961.)

537.56:621.372.8 2157

The Influence of the Langmuir Stratum between Plasma and Container Wall on Wave Propagation in a Plasma Cable—W. O. Schumann. (*Z. angew. Phys.*, vol. 12, pp. 298–300; July, 1960.) See also 1121 of April.

538.12:538.221 2158

Field External to Open-Structure Magnetic Devices Represented by Ellipsoid or Spheroid—H. Chang (*Brit. J. Appl. Phys.*, vol. 12, pp. 160–163; April, 1961.) Mathematical expressions for the fields are given and curves are plotted with dimensional ratio as parameter.

538.56:537.56 2159

The Electromagnetic Fields of a Dipole in the Presence of a Thin Plasma Sheet—J. R. Wait. (*Appl. Sci. Res.*, vol. B8, nos. 5/6, pp. 397–417; 1960.) An extension of Poeverlein's work (3604 of 1958) is given. Under the assumption that the thickness of the slab is small, expressions for the resultant fields are obtained See also 2352.

538.566 2160

Impedance Boundary Conditions for Imperfectly Conducting Surfaces—T. B. A. Senior. (*Appl. Sci. Res.*, vol. B8, nos. 5/6, pp. 418–436; 1960.) It is shown how the exact EM boundary conditions at the surface of a material of large refractive index can be approximated to yield the usual impedance or Leontovich boundary conditions. [See, *e.g.*, 1901 of 1947 (Leontovich and Fock)].

538.566 2161

Propagation of Electromagnetic Surface Waves along Wedge Surfaces—W. E. Williams (*Quart. J. Mech. Appl. Math.*, vol. 13, pt. 3, pp. 278–284; August, 1960.) The conditions under which surface waves can be excited by a plane EM wave incident on a wedge are determined.

538.566 2162

Impedance Boundary Conditions for Statistically Rough Surfaces—T. B. A. Senior. (*Appl. Sci. Res.*, vol. B8, nos. 5/6, pp. 437–462; 1960.)

538.566:535.42 2163

Scalar Diffraction by a Prolate Spheroid at Low Frequencies—T. B. A. Senior. (*Canad. J. Phys.*, vol. 38, pp. 1632–1641; December, 1960.)

538.566:535.43 2164

Scattering by a Narrow Unidirectionally Conducting Infinite Strip—S. R. Seshadri. (*Canad. J. Phys.*, vol. 38, pp. 1623–1631; December, 1960.) Expressions for the far-zone fields and the first two terms in the series for the total scattering cross section are obtained.

538.566:535.43 2165

Backscattering from a Conducting Cylinder with a Surrounding Shell—M. A. Plonus. (*Canad. J. Phys.*, vol. 38, pp. 1665–1676; December, 1960.)

538.566:535.43 2166

Scattering by a Grating: Parts 1 and 2—R. F. Millar. (*Canad. J. Phys.*, vol. 39, pp. 81–118; January, 1961.) Anomalies occur in the angular spectrum of plane waves scattered by a grating when any of the waves propagate tangentially along the surface. This behavior is analyzed theoretically for a wave function vanishing on the grating elements, and for the derivative of the wave function vanishing.

538.566:537.56 2167

Nonlinear Interaction of an Electromagnetic Wave with a Plasma Layer in the Presence of a Static Magnetic Field: Part 1—Theory of Harmonic Generation—R. F. Whitmer and E. B. Barrett. (*Phys. Rev.*, vol. 121, pp. 661–668; February, 1961.) Theory of propagation through an anisotropic ionized layer, as a function of H, n_e, ν, incident field strength, and layer thickness, is presented.

538.566.2 2168

Penetration of Microwaves into the Rarer Medium in Total Reflection—J. J. Brady, R. O. Brick, and M. D. Pearson. (*J. Opt. Soc. Am.*, vol. 50, pp. 1080–1084; November, 1960.) Using right-angle prisms separated by a narrow air gap, transmission and reflection coefficients of paraffin, sulphur and NaCl have been measured at 3 cm λ as a function of the gap width.

538.566.2 2169

Refraction and Diffraction of Pulses—W. E. Williams. (*Canad. J. Phys.*, vol. 39, pp. 272–275; February, 1961.) A solution for reflection and refraction of a plane pulse at a plane surface is obtained by Fourier synthesis using a method which is also valid when total reflection occurs.

538.569.4:535.853 2170

A Spectrometer for Paramagnetic Electron Resonance with Different Methods of Detection—D. Bösnecker. (*Z. angew. Phys.*, vol. 12, pp. 306–314; July, 1960.) The equipment described can be used for the klystron frequency-modulation and magnetic sweep methods of measurement.

538.569.4:538.221 2171

Theory of Ferro- and Antiferro-magnetic Resonance Absorption—T. Oguchi and A. Honma. (*J. Phys. Soc. Japan*, vol. 16, pp. 79–94; January, 1961.)

538.569.4:538.221:621.318.134 2172

Longitudinal Ferrimagnetic Resonances—R. K. Wangsness. (*Phys. Rev.*, vol. 121, p. 472; January, 1961.) Susceptibility components are calculated for a triangular ferrimagnetic system when the oscillating field is parallel to both the constant field and the net magnetization. See also 499 of February.

538.569.4:538.221:621.318.134 2173

The Relation of Transition Parameters for Linear Processes to Measurable Parameters in Ferrimagnetic Resonance—P. E. Seiden. (*J. Phys. Chem. Solids*, vol. 17, pp. 259–266; January, 1961.) Calculated expressions include the effect of the reaction of spin waves back on to the uniform precession. The consequences of its neglect in previous calculations by others are discussed.

538.569.4:621.375.9:535.61–1/2 2174

Confocal Multimode Resonator for Millimetre through Optical Wavelength Masers—G. D. Boyd and J. P. Gordon. (*Bell Sys. Tech. J.*, vol. 40, pp. 489–508; March, 1961.) The mode patterns and diffraction losses are obtained for a resonator formed by two concave spherical reflectors. These are shown to be a minimum when the reflector spacing equals the common radius of curvature of the reflectors. The optical alignment is not extremely critical.

538.569.4:621.375.9:535.61–2 2175

Resonant Modes in a Maser Interferometer—A. G. Fox and T. Li. (*Bell Sys. Tech. J.*, vol. 40, pp. 453–488; March, 1961.) A theoretical investigation is made of the diffraction of EM waves in Fabry-Perot interferometers when used as resonators in optical masers. Curves for field distribution and diffraction loss are given for different mirror geometries and different modes.

539.2 2176

Collective Excitation of Electrons in Degenerate Bands: Part 2—Collective Excitations in a Metallic *p*-Band—T. Izuyama. (*Prog. Theoret. Phys.*, vol. 24, pp. 899 907; October, 1960.) Part 1: 827 of March.

GEOPHYSICAL AND EXTRA-TERRESTRIAL PHENOMENA

523.164:621.396.677 2177

The Radio Telescope for 7.9 Metres Wavelength at the Mullard Observatory—C. H. Costain and F. G. Smith. *Monthly Notices Roy. Astron. Soc.*, vol. 121, no. 4, pp. 405–412; 1960.) The pencil-beam system described is based on the principle of aperture synthesis and has a resolution of $0.8° \times 0.8°$. A survey of the sky between R.A. 05^h and 17^h, declination $+10°$ to $+50°$ is given.

523.164.4 2178

The Radio Spectrum of the Andromeda Nebula.—J. E. Baldwin and C. H. Costain. (*Monthly Notices Roy. Astron. Soc.*, vol. 121, no. 4, pp. 413–417; 1960.) New observations have been made at 38 and 178 Mc. Results are compared with those made at Jodrell Bank at 408 Mc by Large, *et al.* (2937 of 1959) and show that all parts of the nebula have a similar spectrum.

523.165 2179

Asymmetry in the Recovery from a Very Deep Forbush-Type Decrease in Cosmic-Ray Intensity—D. C. Rose and S. M. Lapointe. (*Canad. J. Phys.*, vol. 39, pp. 239–251; February, 1961.) The intensity-time curve for cosmic rays recorded at 30 locations all over the world is analyzed. Recovery occurred at each station at the same effective local time, corresponding to arrival from directions making 15° and 165° with the sun-earth line.

523.165:523.75 2180

Cosmic-Ray Flare of November 20, 1960—R. T. Hansen. (*Phys. Rev. Lett.*, vol. 6, pp. 260–262; March, 1961.) A solar flare was observed visually at a height at least 10^5 km above the chromosphere, at a time which corresponds with a period of increased cosmic-ray neutron flux and a burst in solar noise flux [1496 of May (Covington and Harvey)].

523.165:550.383.4 2181

The Drift Velocity of Charged Particles in the Magnetic Dipole Field—M. Siebert. (*Naturwiss.*, vol. 47, p. 351; August, 1960.) A more accurate expression for the drift velocity of particles in the vicinity of the equator is derived by allowing for a second centrifugal-force term in the original equation.

523.165:550.385 2182

Equation of a Charged Particle Shell in a Perturbed Dipole Field—R. H. Pennington. (*J. Geophys. Res.*, vol. 66, pp. 709–712; March, 1961.) The equation obtained agrees with the shell measured by satellite 1958 E following the nuclear explosion of September 6, 1958.

523.165:550.385.4 2183

Effect of Hydromagnetic Waves in a Dipole Field on the Longitudinal Invariant—E. N. Parker. (*J. Geophys. Res.*, vol. 66, pp. 693–708; March, 1961.) Hydromagnetic waves of period 1 second and amplitude 10^{-3} G at 6 earth radii may cause a systematic lowering of mirror points with subsequent loss of particles in atmospheric collisions. Two models for electron density variation along a field line are investigated. Particle acceleration by the Fermi process is dominated by particle loss at mirror points, and it is suggested that only high-frequency waves will give effective acceleration. See also 533 of February.

523.165:550.385.4 2184

Preliminary Report on Cosmic-Ray Intensity during Magnetic Storms in July 1959—J. G. Roederer, O. R. Santochi, J. C. Anderson, J. M. Cardoso and J. R. Manzano. (*Nuovo Cim.*, vol. 18, pp. 120–130; October, 1960. In English.) Observations at three stations show that there was no appreciable change in the primary variation spectrum for three successive Forbush decreases. This may be interpreted as an indication of a linear superposition of cosmic-ray modulation effects during the July disturbances. For an analysis of cosmic-ray intensity recorded at Mina Aguilar during this period as a function of time, see *Ibid.*, pp. 131–135.

523.165:550.385.4 2185

Cosmic-Ray Intensity Variations during the Magnetic Storm in May 1959—J. R. Manzano, J. G. Roederer and O. R. Santochi. (*Nuovo Cim.*, vol. 18, pp. 136–146; October, 1960. In English.) The primary variation spectrum has been estimated in a similar manner to that used for the July storms (see 2184). Results for both storm periods have been compared, showing a number of common features.

523.3:621.396.96 2186

Some Properties of Radio Waves Reflected from the Moon and their Relation to the Lunar Surface—T. Hagfors. (*J. Geophys. Res.*, vol. 66, pp. 777–785; March, 1961.) The properties of the echoes are described in terms of the correlation of the complex amplitudes of two sine waves at frequencies separated by $\Delta\omega$, reflected from the surface. The correlation technique can be extended to two-dimensional mapping of a rotating rough body. A statistical model of the lunar surface roughness is derived in which rms slopes of 1/20 to 1/10 are assumed.

523.3:621.396.96 2187

A Method of Evaluating the Intensity of Radio Signals Reflected from the Surface of the Moon—M. P. Dolukhanov. (*Radioteknika* (*Moscow*), vol. 15, pp. 5–8; May, 1960.) Propagation losses can be determined by supposing that the reflected wave is formed within the limits of the first Fresnel half-zone and taking account of the curvature of the reflecting surface. The method provides a more accurate picture of the reflection phenomena.

550.385 2188

Some Evidence of Hydromagnetic Waves in the Earth's Magnetic Field—M. Sugiura. (*Phys. Rev. Lett.*, vol. 6, pp. 255–257; March, 1961.) Combining changes in the H and D components of field indicate that the horizontal magnetic vector is elliptically polarized. This may be due to a hydromagnetic wave traveling obliquely to the earth's magnetic field.

550.385 2189

Low-Latitude and High-Latitude Geomagnetic Agitation—E. R. Hope. (*J. Geophys. Res.* vol. 66, pp. 747–776; March, 1961.) Detailed study is made of geomagnetic agitation (ΔH). Above 60° the three daily maxima of ΔH have spiral loci. Agitation is an order of magnitude lower at middle latitudes increasing again towards the equator. Ionospheric current systems (with auroral electro-jets) are examined in the above context. The occurrence frequency of sudden commencements at one station exhibits a diurnal variation. A recent theoretical explanation of this is examined. Over 100 references.

550.385.2 2190

On the Seasonal Variation in Lunar and Solar Geomagnetic Tides in the Geomagnetic Equatorial Region—K. S. Raja Rao. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 289–294; April, 1961.)

550.385.4:523.746 2191

Influence of Sunspots on Geomagnetic Disturbance—F. Ward and R. Shapiro. (*J. Geophys. Res.*, vol. 66, pp. 739–746; March, 1961.) "The hypothesis that the ejection of solar corpuscles is influenced by interactions of 'active region' magnetic fields is tested empirically. The results do not support the hypothesis."

550.385.4:551.594.5 2192

Dipole-Field Type Magnetic Disturbances and Auroral Activities—B. K. Bhattacharyya. (*Canad. J. Phys.*, vol. 39, pp. 350–366; February, 1961.) The magnetic perturbation produced at the ground by the current system associated with an electric dipole at 100 km is calculated. Magnetograms obtained during an auroral display are analyzed to deduce the position and motion of the equivalent dipoles. These correspond closely with prominent visual auroral forms.

551.507.362.2 2193

Minimum Range to Artificial Earth Satellites—K. Toman. (*Nature*, vol. 190, pp. 333–334; April, 1961.) A complete expression for calculating, from Doppler measurements, the minimum passing range between satellite and observer is derived, and its application under various orbital conditions is discussed.

551.507.362.2 2194

Loss of Mass in Echo Satellite—I. I. Shapiro and H. M. Jones. (*Science*, vol. 133, p. 579; February, 1961.) A correction to 1157 of April and comparison of predictions with observed orbital data are given.

551.507.362.2 2195

Spin-Rate of the Satellite Echo I as Determined by a Tracking Radar—G. E. K. Lockwood. (*Canad. J. Phys.*, vol. 38, no. 12, p. 1713; 1960.) Radar observation of Echo I (1960 ι) indicate that between passes 131 and 217 the spin rate increased from 1.63 to 1.88 rpm. Between these two observations the satellite first started passing into the earth's shadow, which possibly resulted in changes in internal pressure and subsequent deformation of the balloon.

551.507.362.2:621.396.934 2196

New Satellite Tracking Station in Great Britain—(See 2375.)

551.510.53 2197

Magnesium and Calcium Ions in the Upper Atmosphere of the Earth—V. G. Istomin. (*Dokl. Akad. Nauk SSSR*, vol. 136, pp. 1066–1068; February, 1961.) The presence of Mg^+ and Ca^+ ions was recorded by a rocket-borne mass spectrometer launched from a moderate latitude. Peaks in the Mg^+ ion concentration reaching $1.36\times10/^4\text{cm}^3$ were observed at heights of 103.5 and 105 km.

551.510.53:551.507.362 2198

Daytime and Nighttime Atmospheric Properties Derived from Rocket and Satellite Observations—H. K. Kallmann-Bijl. (*J. Geophys. Res.*, vol. 66, pp. 787–795; March, 1961.) A summary of the values of atmospheric density obtained during the interval from 1957 to 1960 from rockets and satellites is presented, and is fitted into a model atmosphere obtained by integrating the hydrostatic equation. A general decrease since 1957 in atmospheric density at all altitudes is confirmed.

551.510.535 2199

Rocket Electron Density Measurements at Fort Churchill, Canada—A. W. Adey and W. J. Heikkila. (*Canad. J. Phys.*, vol. 39, pp. 219–221; January, 1961.) A discussion is given of the results of a rocket flight during quiet ionospheric conditions using the two-frequency phase-comparison technique of Seddon (402 of 1954.)

551.510.535 2200

Longitudinal and Latitudinal Effect of the Ionosphere Estimated by Observation on Board the Soya—H. Shibata, K. Sawada and S. Taguchi. (*J. Radio Res. Labs., Japan*, vol. 7, pp. 575–582; November, 1960.) Values of f_0F_2 at hourly intervals are plotted against geomagnetic latitude for the range 10°S–70°S covered by the voyages from Japan to Antarctica in December and January, 1956–1957, 1958–1959, and 1959–1960.

551.510.535 2201

Ionization of *E* Layer by X-Rays—S. N. Ghosh and S. Nand. (*Indian J. Phys.*, vol. 34, pp. 516–526; November, 1960.) The total amount of solar X-ray energy absorbed within the E layer is calculated from available rocket and absorption measurements. Only X rays in the wavelength region 5–100°A are absorbed, the amount of energy involved being estimated at 0.19 erg cm^{-2} sec^{-1}.

551.510.535 2202

Some Observations of the Occurrence and Movement of Sporadic-*E* Ionization—J. Harwood. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 243–262; April, 1961.) An analysis is given of simultaneous observations of E_s clouds in Europe by ionosondes at various locations, by a 17-Mc rotating-antenna back-scatter sounder at Slough, England, and by an oblique-propagation experiment at 17 Mc over 700 km. The mean cloud diameter was about 200 km. About twice as many clouds occurred to the south of Slough as to the north with an average duration of $2\frac{1}{2}$ hours. Of 143 clouds, one third drifted, predominantly to the southwest, at a mean speed of 60 m. The movement of the clouds did not correlate with wind velocities.

551.510.535 2203

The *F* Layer at Sunrise—M. Rishbeth and C. S. G. K. Selty. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 263–276; April, 1961.) Observations at Cambridge and Slough, England, show that at fixed heights in the F region, just after layer sunrise, the electron density increases faster in winter than in summer, and faster at sunspot maximum than at sunspot minimum. It is postulated that seasonal changes of atmospheric composition alter the rates of electron production and loss, thereby causing both the "noon" and "sunrise" seasonal F_2-layer anomalies.

551.510.535 2204

Diffusion of Ionization in the Sunrise *F* Layer—H. Rishbeth. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 277–288; April, 1961.) Some idealized calculations support the assumption made in the previous paper that the rare of increase of F-region electron density, just after sunrise, depends primarily on the rate of production of ionization. At this time the loss, diffusion and transport of ionization are of secondary importance.

551.510.535 2205

Travelling Disturbances in the *F* region over Waltair—E. B. Rao and B. R. Rao. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 296–297; April, 1961.) A description is given of the general diurnal and seasonal characteristics of traveling disturbances as observed on $P'(t)$ and $P'(f)$ records extending over two years.

551.510.535:523.164:550.385.37 2206

Simultaneous Observations of Pulsations in the Geomagnetic Field and in Ionospheric Absorption—S. Ziauddin. (*Canad. J. Phys.*, vol. 38, pp. 1714–1715; December, 1960.) On September 20 and 21, 1959, at 0700 L.M.T. regular pulsations were recorded simultaneously on a) a riometer operating on a frequency of 34 Mc and b) a magnetometer measuring the H component of the geomagnetic field. For many cycles the pulsations remain in phase but on occasions they are in antiphase. The period of the geomagnetic pulsations suggests that they are due to toroidal hydromagnetic oscillations of the outer atmosphere; possible connections with ionospheric absorption are briefly considered.

551.510.535:523.745 2207

Analysis of the Variation of f_0E and Index of Solar Activity—H. Shibata and S. Watanabe. (*J. Radio Res. Labs, Japan*, vol. 7, pp. 621–635; November, 1960.) It is assumed that, for both the diurnal and annual changes in f_0E, the critical frequency is proportional to $\cos^{\frac{1}{4}} \chi$. The values of f_0E are extrapolated to $\chi=0$ for several stations and an empirical relation between the values for $\chi=0$ and the sunspot number is derived.

551.510.535:550.385 2208

Vertical Drift in the *E* layer of the Ionosphere during Geomagnetic Disturbances—H. Kohl. (*Arch. elekt. Übertragung*, vol. 14, pp. 314–316; July, 1960.) The velocity is estimated of the vertical drift due to geomagnetic disturbances. The possible rise of the E layer is shown to be only a few hundred meters which cannot be measured by ionospheric recorders. For an investigation of F-layer movements, see 1848 of June.

551.510.535:621.3.087.4 2209

Active High-Frequency Spectrometers for Ionospheric Sounding: Part 1—Direct Recording of Ionospheric Characteristics—K. Bibl. (*Arch. elekt. Übertragung*, vol. 14, pp. 341–347; August, 1960.) On the basis of the method not noted earlier (2729 of 1956), equipment has been designed which provides direct records of M.U.F., h' and f_n as a function of time. Sample records are reproduced and applications of the method are discussed. A method of distinguishing height ranges in F-layer $f_n(t)$ records using color film is noted.

551.510.535:621.391.812.3 2210
Analysis of Random Fading Records—Khastgir and Singh. (See 2357.)

551.510.535:621.391.812.63 2211
Measurement of the Ionospheric Absorption during the I.G.Y. at Kokubunji—J. Yasuda and H. Sugiuchi. (*J. Radio Res. Labs., Japan*, vol. 7, pp. 551–574; November, 1960.) The diurnal variation in absorption shows an asymmetry about noon which is attributed to the changes in vertical drift motion in the D layer associated with the Sq current system. The marked winter anomaly effect cannot be explained by a change in the electron density distribution in the normal D layer.

551.510.535:621.391.812.63 2212
Ionospheric Motions Observed with High Frequency Back-Scatter Sounders—L. H. Tveten. (*J. Res. NBS*, vol. 65D, pp. 115–127; March and April, 1961.) "Techniques for determining the characteristics of movements of irregularities in the F_2-region by the use of backscatter records are described. The results of an analysis of backscatter data obtained during December 1952, at Sterling, Virginia, at a frequency of about 13.7 Mc/s are presented and found to be in good agreement with those of other investigators of ionospheric motions."

551.510.535:621.391.812.63.029.62/.63 2213
Effect of the Magnetic Field in Ionospheric Back-Scatter—E. E. Salpeter. (*J. Geophys. Res.*, vol. 66, pp. 982–984; March, 1961.) Backscatter spectral lines may be used to calculate magnetic field, ion mass and plasma temperature. See also 1290 of April (Fejer).

551.510.535(98):621.391.812.631 2214
High-Frequency Radio-Wave Blackouts at Medium and High Latitudes during a Solar Cycle—Collins, Jelly, and Matthews. (See 2351.)

551.594.5 2215
Theory of Auroral Morphology—J. W. Kern and E. H. Vestine. (*J. Geophys. Res.*, vol. 66, pp. 713–723; March, 1961.) The theory is based on the production of instabilities in electron sheets. It predicts observed features relating to the duration of homogeneous arcs and the transition from glow to homogeneous arcs to ray arcs and draperies. Other observations explained are certain phenomena in flaming auroras and the lowering of mirror points in certain conditions.

551.594.5 2216
Reply to Some Comments by Malville concerning the Midnight Auroral Maximum—E. H. Vestine and J. W. Kern. (*J. Geophys. Res.*, vol. 66, pp. 989–991; March, 1961.) The preponderance of aurora near magnetic midnight is discussed. See 149 of January (Malville).]

551.594.5:550.385.4 2217
The Relationship between Unique Geomagnetic and Auroral Events—Y. Sobouti. (*J. Geophys. Res.*, vol. 66, pp. 725–737; March, 1961.) At eleven Canadian stations, a high correlation is found between the geomagnetic latitudes of the southern extents of auroras and the most southerly current lines. A southward drift occurs simultaneously in an aurora and the accompanying ionospheric currents.

551.594.5:551.510.535 2218
Relationship between Red Auroral Arcs and Ionospheric Recombination—G. A. M. King and F. E. Roach. (*J. Res. NBS*, vol. 65D, pp. 129–135; March and April, 1961.) An auroral arc (6300Å), observed photometrically to be north of Boulder, Colo., has been identified with oblique echoes on ionograms taken near Boulder.

551.594.6 2219
Generation of Very-Low-Frequency Noise in the Exosphere by the Cerenkov Effect—R. Gendrin. (*Compt. rend. Acad. Sci., Paris*, vol. 251, pp. 1122–1123; September, 1960.) The Čerenkov effect, produced by relatively slow-moving particles of solar origin, is considered as a possible mechanism for the generation and propagation of VLF noise. The theory is briefly discussed in relation to a "traveling-wave tube" model proposed by Gallet (1575 of 1959) to explain similar VLF emissions.

551.594.6 2220
Energy Fluxes from the Cyclotron Radiation Model of VLF Radio Emission—W. B. Murcray and J. H. Pope. (Proc. IRE, vol. 49, pp. 811–812; April, 1961.) Comment on a paper by Santirocco (4253 of 1960) is given.

551.594.6 2221
Classification of the Waveforms of Atmospherics—S. R. Khastgir and R. S. Srivastava. (*J. Inst. Telecommun. Engrs., India*, vol. 6, pp. 260–265; October, 1960.) A review with 28 references is given.

551.594.6 2222
The Determination of the Distance of Atmospherics from their Waveform—R. Schminder. (*Met. Zeit.*, vol. 14, pp. 212–217; July-September, 1960.) Diagrams facilitating the determination of the distance of atmospherics are given; their use is discussed with reference to the results of measurements. A reflection height of 70 km was assumed for daytime conditions, and 90 km for nighttime propagation.

551.594.6 2223
Guidance of Radio Whistlers by the Earth's Magnetic Field—R. Gendrin. (*Compt. rend. Acad. Sci., Paris*, vol. 251, pp. 1085–1087; August, 1960.) In an anisotropic medium there is for each frequency an emission angle ($\theta \neq 0$ of such a value that the ray propagates strictly along the line of magnetic force with a velocity which is independent of frequency.

551.594.6 2224
Remarks on the Annual and Diurnal Variations of the Occurrence of Whistlers—L. Klinker and G. Entzian. (*Met. Zeit.*, vol. 14, pp. 207–212; July-September, 1960.) The annual variation of whistler density observed at Kühlungsborn appears to be correlated with the thunderstorm activity of South Africa and not with that of the conjugate point which is at a higher geomagnetic latitude. Noctural variations of whistler density show phase differences between summer and winter, which are attributed to absorption in the lower ionosphere.

551.594.6 2225
The Hydrogen Ion Effect in Whistler Dispersion—R. E. Barrington and T. Nishizaki. *Canad. J. Phys.*, vol. 38, pp. 1642–1653; December, 1960.) Careful analysis of four low-altitude whistlers shows deviations at low frequencies from the law $tf^{\frac{1}{2}} = \text{const.}$ This observation is explained in terms of a simple atmospheric model in which the gas above about 1000 km is mainly hydrogen.

551.594.6:621.3.087.4 2226
Initial Results of a New Technique for Investigating Sferic Activity—G. Hefley, R. H. Doherty and R. F. Linfield. (*J. Res. NBS*, vol. 65D, pp. 157–166; March and April, 1961.) The system was developed for the automatic measurement of the complex spectral characteristics and for the automatic high-speed processing of statistical data. Typical results are presented and discussed.

LOCATION AND AIDS TO NAVIGATION

534.88 2227
Prospects and Limitations of the Use of Low Frequencies in Echo Location—G. Pazienza. (*Alta Frequenza*, vol. 29, pp. 323–336; June-August, 1960.) The frequency dependence of the parameters which determine the range of underwater echo-location equipment is investigated. The ranges obtainable at frequencies between 2 and 30 kc are calculated, and the problem of noise interference is discussed.

621.396.96:621.375.9:621.372.44 2228
Radar Sensitivity with Degenerate Parametric Amplifier Front End—J. C. Green, W. D. White, and R. Adler. (Proc. IRE, vol. 49, pp. 804–807; April, 1961.)

621.396.962.3:621.372.54 2229
General Matched-Filter Analysis of Linear FM Pulse Compression—G. E. Cook. (Proc. IRE, vol. 49, p. 831; April, 1961.) An extension of earlier work (2023 of 1960) is given.

621.396.963:621.396.65 2230
Remote Presentation of Radar Information—G. N. S. Taylor. (*Point to Point Telecommun.*, vol. 5, pp. 18–27; February, 1961.) The use of microwave links is discussed.

621.396.969.36 2231
Proposed Monocycle-Pulse Very-High-Frequency Radar for Air-Borne Ice and Snow Measurement—J. C. Cook. (*Commun. and Electronics*, no. 51, pp. 588–594; November, 1960. Discussion.) A method is proposed for investigating from the air the thickness of ice and snow masses. The system operating at about 100 Mc would radiate a single wave train from a spark gap, with the charge conductors shaped to encourage radiation of all frequency components in the spectrum of a short pulse.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.7 2232
Hot-Cathode Magnetron Ionization Gauge for the Measurement of Ultra High Vacua—J. M. Lafferty. (*J. Appl. Phys.*, vol. 32, pp. 424–434; March, 1961.) To extend the low pressure limit, an increase in the ratio of ion current to X-ray photocurrent is necessary. A magnetron gauge is discussed which is linear down to a pressure of 4×10^{-14} mm Hg.

533.583:621.385.832 2233
The Determination of the Quantity of Barium Evaporated from Getters—P. Della Porta and S. Origlio. (*Le Vide*, vol. 15, pp. 446–455; November/December, 1960. In French and English.) The complexometric method described is applied in the determination of the distribution of Ba on the screen of a television tube when using different shapes of getter.

535.215 2234
Effect of Photoexcitation on the Mobility in Photoconducting Insulators—R. H. Bube and H. E. MacDonald. (*Phys. Rev.*, vol. 121, pp. 473–483; January, 1961.) The Hall mobility of carriers in photoconducting insulators can be varied over an appreciable range by the effects of photoexcitation. Suitable use of the phenomena leads to knowledge about carrier density, sign and mobility, and also gives information about the charge on and the cross section of the imperfection centers. Experiments on CdS and CdSe single crystals with conductivities in the range 10^{-9}–10^{-1} mho/cm illustrate the potentialities of the technique.

535.215:546.28 2235
Some Preliminary Experiments Concerning the Influence of Band Bending on Photoelectric Emission—J. J. Scheer. (*Philips Res. Repts.*, vol. 15, pp. 584–586; December, 1960.) "The theory that *p*-type semiconductors should exhibit a higher photoelectric quantum efficiency than *n*-type semiconductors is verified by measurements of the photoemission from cesium-covered silicon surfaces."

535.215:546.48'221 2236
Cadmium Sulphide Photoconductive Sintered Layers—M. J. B. Thomas and E. J. Zdanuk. (*J. Electrochem. Soc.*, vol. 106, pp. 964–971; November, 1959.) Dependence of photoconduction characteristics on the composition and formation of layers is investigated.

535.215:546.48'221 2237
The Effect of Mechanical Surface Treatment on the Fine Structure of the Spectral Curves of Photoconductivity in Cadmium Sulphide Crystals—E. F. Gross and B. V. Novikov. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1882–1885; December, 1959.)

535.215:546.48'221 2238
The Change of the Real Structure of CdS Single Crystals due to the Evaporation of Lattice Constituents in a Vacuum—K. W. Böer, H. Hornung, and K. Zimmermann. (*Mber. dtsch. Akad. Wiss. Berlin*, vol. 2, nos. 3/4, pp. 159–161; 1960.) A report of heat-treatment tests on high-purity CdS crystals is given. Evaporation of Cd was observed at 380°C.

535.215:546.48'221 2239
Influence of a Hydrogen Atmosphere on the Photoconduction of CdS Single Crystals—M. Asche and F. Eckart. (*Mber. dtsch. Akad. Wiss. Berlin*, vol. 2, no. 5, pp. 261–266; 1960.)

535.215:546.48'221 2240
Remarks on the Photoconduction of CdS Single Crystals with Excitation at the Fundamental Lattice Absorption Edge—H. Gutjahr. (*Mber. dtsch. Akad. Wiss. Berlin*, vol. 2, no. 5, pp. 269–271; 1960.)

535.215:546.48'221 2241
The Influence of Annealing in Vacuum and in Sulphur Vapour on the Real Structure of CdS Single Crystals—K. W. Böer, H. Gutjahr, and H. Hornung. (*Z. Phys.*, vol. 159, pp. 495–504; August, 1960.) Investigations of the spectral distribution of photoconductivity are given. [See also 1190 of April (Berger, *et al.*)].

535.215:546.48'221 2242
Photoconductivity of CdS-Type Photoconductors in the Vicinity of the Absorption Edge—N. N. Winogradoff. (*J. Appl. Phys.*, vol. 32, pp. 506–609; March, 1961.) A new model for the photoconductivity mechanism is discussed.

535.215:546.48'221:538.63 2243
The Influence of Temperature and Ambient Conditions on the Photoelectromagnetic (PEM) Effects in CdS—(*J. Phys. Chem. Solids*, vol. 18, pp. 261–262; February, 1961. In German.)

535.215:546.817'231 2244
The Preparation of Vapour-Deposited Lead Selenide Films of High Mechanical and Electrical Stability—H. Gobrecht, F. Niemeck and K. E. Boeters. (*Z. Phys.*, vol. 159, pp. 533–540; August, 1960.)

535.376:546.47'221 2245
Electroluminescence—a Disorder Phenomenon—D. W. G. Ballentyne. (*J. Electrochem. Soc.*, vol. 107, pp. 807–810; October, 1960.) Experimental investigations show that electroluminescence only occurs in ZnS powders containing both sphalerite and wurtzite. This observation suggests that electroluminescence is a disorder phenomenon associated with stacking faults in the crystal.

535.376:546.47'221 2246
The Action of Nickel and Cobalt in Electroluminescent Zinc Sulphide Phosphors—P. Goldberg. (*J. Electrochem. Soc.*, vol. 106, pp. 948–954; November, 1959.) Luminescence characteristics are studied as a function of voltage, frequency, and concentration of Ni and Co. See also 2082 of 1956 (Lehmann: Haake).

537.226.8 2247
The Temperature Dependence of Dielectric Constants—E. E. Havinga. (*J. Phys. Chem. Solids*, vol. 18, pp. 253–255; February, 1961.) For isotropic and for cubic materials three factors contribute to the temperature dependence: the influences of volume expansion and of temperature on polarizability, and a direct volume-expansion effect. A simple method is given for determining the values of the separate contributions.

537.227 2248
Contribution to the Theory of Ferro- and Antiferro-electrics—V. I. Klyachkin. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1874–1877; December, 1959.)

537.227:546.431'824–31 2249
Quantitative Study of Low-Frequency Hysteresis Loops of Polarized Polycrystalline Barium Titanate—G. W. Marks and D. A. Hanna. (*Commun. and Electronics*, pp. 799–808; January, 1961.)

537.227:547.476.3 2250
Measurement of the Dielectric Nonlinearity of Rochelle Salt—H. E. Müser. (*Z. angew. Phys.*, vol. 12, pp. 300–306; July, 1960.) Discrepancies between measured values of coercivity and those predicted by the theory of the dielectric properties of Rochelle salt are investigated with reference to ferroelectric hysteresis measurements (3008 of 1959).

537.227:547.476.3 2251
The Origin of the Optical Representation of the Ferroelectric Domains of Rochelle Salt Crystals—H. Flunkert. (*Z. Phys.*, vol. 159, pp. 253–271; July, 1960.) A quantitative interpretation of observed interference effects is given, and an appropriate domain model is proposed.

537.228.1:546.431'824–31 2252
Effect of Pressure on the Piezoelectric Properties of Barium Titanate—B. A. Rotenberg. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1777–1781; December, 1959.)

537.228.1:546.431'824–31 2253
The Depolarization Charge of Barium Titanate and its Connection with the Piezoelectric Effect—F. I. Kolomoĭtsev and I. A. Izhak. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1791–1793; December, 1959.) The sign of the surface charge during depolarization always corresponds to the sign of the piezoelectric charge during compression. The charge released during heating near the Curie point is directly proportional to the size of the piezoelectric modulus.

537.228.1:549.514.51 2254
Piezoelectric Behaviour of Impacted Quartz—R. A. Graham. (*J. Appl. Phys.*, vol. 32, p. 555; March, 1961.)

537.311.31+537.312.62]:538.632 2255
Frequency-Dependent Hall Effect in Normal and Superconducting Metals—P. B. Miller. (*Phys. Rev.*, vol. 121, pp. 435–450; January, 1961.) Calculations are made of the Hall current flow when an EM wave is incident on the metal in a static magnetic field. The entire frequency range is considered, with emphasis on the microwave region.

537.311.33 2256
Recombination of Charge Carriers in Semiconductors with Any Conception of Recombination Centres—K. Thiessen. (*Mber. dtsch. Akad. Wiss. Berlin*, vol. 2, nos. 3/4, pp. 149–158; 1960.) Calculations of lifetimes are based on the existence of two trapping levels.

537.311.33 2257
Disturbances of Carrier Concentration in High Electric Field—E. M. Conwell. (*J. Phys. Chem. Solids*, vol. 17, pp. 342–344; January, 1961.) Consideration of recombination of hot carriers on the basis of the Shockley-Read model for thermal carriers (420 of 1953) leads to a prediction of changes in carrier concentration occurring as a bulk effect in high fields.

537.311.33 2258
Decay of Excess Carriers in Semiconductors: Part 2—K. C. Nomura and J. S. Blakemore. (*Phys. Rev.*, vol. 121, pp. 734–740; February, 1961.) Theory of recombination of excess carriers, for large or small excess carrier densities, is presented for the case in which the trapping level and Fermi level of the intrinsic gap lie in opposite halves. Part 1: 1915 of 1959.

537.311.33 2259
Physical Properties of Several II–V Semiconductors—W. J. Turner, A. S. Fischler, and W. E. Reese. (*Phys. Rev.*, vol. 121, pp. 759–767; February, 1961.) Energy gaps and mobilities have been measured in Zn_3As_2, $ZnAs_2$, ZnSb, Cd_3As_2, $CdAs_2$ and CdSb. For $CdAs_2$ the resistivity and mobility anisotropy have also been investigated.

537.311.33 2260
Composition Stability Limits of Binary Semi-conductor Compounds—R. F. Brebrick. (*J. Phys. Chem. Solids*, vol. 18, pp. 116–128; February, 1961.)

537.311.33 2261
Extended Curves of the Space Charge, Electric Field, and Free Carrier Concentration at the Surface of a Semiconductor, and Curves of the Electrostatic Potential Inside a Semiconductor—C. E. Young. (*J. Appl. Phys.*, vol. 32, pp. 329–332; March, 1961.) The work of Kingston and Neustadter (3300 of 1955) has been extended, and curves are given which apply to materials of higher energy gap. Curves of electrostatic potential inside a semiconductor supplement are those given by Dousmanis and Duncan (848 of 1959).

537.311.33:538.569.4 2262
Cyclotron and Paramagnetic Resonance in Strained Crystals—G. E. Pikus and G. L. Bir. (*Phys. Rev. Lett.*, vol. 6, pp. 103–105; February, 1961.) Possible applications of resonance measurements on strained crystals are discussed, in particular the determination of the ratio of deformation potentials, investigation of semiconductors with toroidal energy surfaces, and the observation of spin resonance of free carriers in *p*-type Ge and Si.

537.311.33:546.23 2263
The Influence of Tl and TlCl Impurities on the Conductivity and Photoconductivity of Selenium—I. P. Shapiro. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1782–1785; December, 1959.)

537.311.33:546.24 2264
Magnetic Susceptibility and Galvanomagnetic Effects in Pure and *p*-Type Tellurium—G. Fischer and F. T. Hedgcock. (*J. Phys. Chem. Solids*, vol. 17, pp. 246–253; January, 1961.)

Experimental studies between 4.2° and 500° K are described and the results discussed.

537.311.33:[546.28+546.289 2265

The Influence of Deformation of the Electrical Properties of p-Germanium and Silicon—G. E. Pikus and G. L. Bir. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1828–1840; December, 1959.) Based on expressions derived earlier (4285 of 1960) a quantitative theory is developed and the changes in conductivity, Hall coefficient and magnetoresistance during uniform deformation are calculated. See 1657 of 1960 (Pikus).

537.311.33:[546.28+546.289 2266

Segregation and Distribution of Impurities in the Preparation of Germanium and Silicon—J. Goorissen. (*Philips Tech. Rev.*, vol. 21, pp. 185–195; June, 1960.) Two variants of the zone-melting technique are described which yield a product in which the concentration of the impurity is uniformly distributed.

537.311.33:546.28 2267

Thermal Expansion of Silicon at Low Temperatures—S. I. Novikova and P. G. Strelkov. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1841–1843; December, 1959.)

537.311.33:546.28 2268

Recombination Radiation from Silicon under Strong-Field Conditions—L. W. Davies and A. R. Storm, Jr. (*Phys. Rev.*, vol. 121, pp. 381–387; January, 1961.) In an attempt to determine the distribution in energy of hot electrons and holes in Si placed in a strong electric field, measurements have been made of the spectral distribution of recombination radiation. The results indicate that intrinsic recombination radiation arises mainly from the decay of excitons rather than from direct recombination of electrons and holes.

537.311.33:546.28 2269

Impurity Conduction in Silicon—R. K. Ray and H. Y. Fan. (*Phys. Rev.*, vol. 121, pp. 768–779; February, 1961.) Various n- and p-type Si samples, of low impurity content, were studied, and conduction due to charge exchange between impurity centers which may be ionized by some compensating impurity was observed. The results are compared with current theories.

537.311.33:546.28 2270

Impact Ionization of Impurities in Silicon—J. C. Sohm. (*J. Phys. Chem. Solids*, vol. 18, pp. 181–195; February, 1961. In French.) Above a certain value of electric field impact, ionization multiplies by avalanche. This phenomenon has been observed in Ge, InP and Si. Experimental data for n- and p-type Si are given.

537.311.33:546.28 2271

Residual Thermoelastic Stresses in Bonded Silicon Wafers—T. D. Riney. (*J. Appl. Phys.*, vol. 32, pp. 454–460; March, 1961.) Stresses are investigated photoelastically. Methods normally employed with isotropic birefringent materials can be used.

537.311.33:546.28 2272

Excess Tunnel Current in Silicon Esaki Junctions—A. G. Chynoweth, W. L. Feldmann, and R. A. Logan. (*Phys. Rev.*, vol. 121, pp. 684–694; February, 1961.) The unexpectedly high excess current flow in Esaki junctions, when a medium forward bias is applied, has been studied experimentally. The results can be accounted for by a mechanism suggested by Yajima and Esaki (1257 of 1959), and an expression is derived for the excess current.

537.311.33:546.281'26:537.583 2273

Electron-Emission-Microscope and Velocity-Distribution Studies on Silicon Carbide p-n Junction Emitters—P. H. Gleichauf and V. Ozarow. (*J. Appl. Phys.*, vol. 32, pp. 549–550; March, 1961.)

537.311.33:546.289 2274

Temperature Dependence of the Low-Frequency Fluctuations of Conductivity in Germanium—M. I. Kornfel'd and D. N. Mirlin. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1866–1868; December, 1959.) The results of measurements at temperatures between −20° and +100°C show that conductivity fluctuations in impure crystals are due to intrinsic conduction and are related to the generation and recombination of electron-hole pairs.

537.311.33:546.289 2275

The Electrical Properties of Semiconductor Grain Boundaries—H. A. Schell and H. F. Mataré. (*Met. Zeit.*, vol. 52, pp. 86–91; January, 1961.) Measurements of electrical characteristics were made at medium-tilt grain boundaries in oriented-growth Ge crystals. Devices based on grain-boundary effects are mentioned.

537.311.33:546.289 2276

Resistivity Striations in Germanium Single Crystals—H. Ueda. (*J. Phys. Soc. Japan*, vol. 16, pp. 61–66; January, 1961.) The relationship shown to exist between the period of the striations, growth rate and temperature gradient near the solid/liquid interface is explained by assuming a super-cooled state in the crystallizing solid/liquid interface.

537.311.33:546.289 2277

Theory of the Magnetic Susceptibility of Holes in Germanium—J. M. Luttinger and P. J. Stiles. (*J. Phys. Chem. Solids*, vol. 17, pp. 284–291; January, 1961.) "The theory of the magnetic susceptibility of free holes is given. A general method of calculation which will work for degenerate as well as simple bands is described, and applied to the valance band of Ge. Results are given for both Maxwell-Boltzmann and Fermi-Dirac statistics, and the possibility of comparison with experiments is discussed."

537.311.33:546.289 2278

Electron-Hole Scattering and Minority-Carrier Mobility in Germanium—T. P. McLean and E. G. S. Paige. (*J. Phys. Chem. Solids*, vol. 18, pp. 139–149; February, 1961.) An extension of earlier work by Paige (1567 of May) by the specific application of the theory to Ge in the temperature and impurity concentration ranges where measurements of the minority-carrier mobility have been made.

537.311.33:546.289 2279

Diffusion of Silver, Cobalt and Iron in Germanium—L. Y. Wei. (*J. Phys. Chem. Solids*, vol. 18, pp. 162–174; February, 1961.)

537.311.33:546.289 2280

Recombination of Excess Carriers at Twin Structures in Germanium—J. P. McKelvey. (*J. Appl. Phys.*, vol. 32, pp. 442–445; March, 1961.) The continuity equation is solved for recombination of excess carriers at twin structures. The twin boundary recombination velocity is determined from lifetime measurements.

537.311.33:546.289 2281

Relation between Surface Concentration and Average Conductivity in Diffused Layers in Germanium—F. B. Cuttrias. (*Bell Sys. Tech. J.*, vol. 40, pp. 509–521; March, 1961.) An expression is derived for the average conductivity of a diffused layer in semiconductor material as a function of the surface concentration of the diffused impurity and the background impurity concentration.

537.311.33:546.289:539.12.04 2282

Change of Surface State of Ge by Electron Bombardment—K. Komatsubara. (*J. Phys. Soc. Japan*, vol. 16, pp. 125–126; January, 1961.) Changes are deduced from observed variations of reverse current.

537.311.33:546.289:539.23 2283

Hall Effect and Conductivity of Thin Vapour-Deposited Germanium Films—F. Eckart and G. Jungk. (*Mber. dtsch. Akad. Wiss. Berlin*, vol. 2, no. 5, pp. 266–269; 1960.) A preliminary report and discussion of Hall-effect and conductivity measurements on films of thickness 800 to 4100 Å at magnetic field strengths up to 10 kg are given.

537.311.33:546.289:539.23 2284

The Low-Temperature Interaction of Oxygen with Evaporated Germanium Films—M. J. Bennett and F. C. Tompkins. [*Proc. Roy. Soc. (London)*, vol. 259, pp. 28–44; November, 1960].

537.311.33:546.289–31 2285

Donor Equilibria in the Germanium-Oxygen System—C. S. Fuller, W. Kaiser, and C. D. Thurmond. (*J. Phys. Chem. Solids*, vol. 17, pp. 301–307; January, 1961.) A more detailed account is given of work reported earlier (1229 of April). Donor formation has been investigated over a wide temperature range in Ge single crystals with well-defined oxygen concentrations. Results confirm that four oxygen atoms are involved in the formation of one donor.

537.311.33:546.33'86 2286

A New Intermetallic Semiconductor Compound—Ya. A. Ugai and T. N. Vigutova. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1786–1788; December, 1959.) A note on the preparation and properties of NaSb with a band gap of 0.82 ev is given.

537.311.33:546.48'811'19 2287

Preparation and Properties of $CdSnAs_2$—A. J. Strauss and A. J. Rosenberg. (*J. Phys. Chem. Solids*, vol. 17, pp. 278–283; January, 1961.) Infrared transmission measurements indicate that the energy gap is about 0.23 ev at room temperature. The absorption edge shifts to shorter wavelengths with increasing electron concentration.

537.311.33:546.681'86 2288

Optical Determination of the Conduction Band Structure of GaSb—M. Cardona. (*J. Phys. Chem. Solids*, vol. 17, pp. 336–338; January, 1961.)

537.311.33:[546.682'19+546.681'19 2289

Electron Effective Masses of InAs and GaAs as a Function of Temperature and Doping—M. Cardona. (*Phys. Rev.*, vol. 121, pp. 752–758; February, 1961.) Faraday rotation and infrared reflectivity measurements were used.

537.311.33:546.682'19 2290

Observation of Oscillatory Magnetoresistance in InAs at Microwave Frequencies—G. Bemski and B. Szymanski. (*J. Phys. Chem. Solids*, vol. 17, pp. 335–336; January, 1961.) Experimental technique and results are described and advantages of microwave measurements over dc measurements are discussed. Similar oscillations have been observed in InSb.

537.311.33:546.682'19:538.639 2291

Magnetothermal Nernst-Ettingshausen Effects in Indium Arsenide—O. V. Emel'yanenko, N. V. Zotova and D. N. Nasledov. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1868–1871; December, 1959.) Graphs show the variation of the Nernst-Ettinghausen coefficients of n-type InAs with temperature up to 600°K. With increase of electron density the point at which the transverse and longitudinal coefficients change sign is displaced towards lower temperatures.

537.311.33:546.682'86 2292

Growth Twins in Indium Antimonide—

R. K. Mueller and R. L. Jacobson. (*J. Appl. Phys.*, vol. 32, pp. 550–551; March, 1961.)

537.311.33:546.682’86 2293

Preparation and Properties of Grown *p-n* Junctions of InSb—H. C. Gorton, A. R. Zacaroli, F. J. Reid, and C. S. Peet. (*J. Electrochem. Soc.*, vol. 108, pp. 354–356; April, 1961.) Grown *p-n* junctions were produced by doping high-purity *n*-type melts with Zn. The curves of current density as a function of temperature showed that leakage currents predominate at lower temperatures and saturation currents at higher temperatures.

537.311.33:546.682’86’241 2294

A New Semiconducting Compound in the In-Sb-Te System—N. A. Goryunova, S. I. Radautsan, and G. A. Kiosse. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1858–1860; December, 1955.) A note on the physico-chemical properties of five InSb-InTe alloys, in particular In_4SbTe_3, a semiconductor, is given.

537.311.33:546.812’231 2295

Electrical Properties of Sb-Doped *n*-Type SnSe—J. Umeda. (*J. Phys. Soc. Japan*, vol. 16, p. 124; January, 1961.)

537.311.33:547.533 2296

Current/Voltage Characteristics of the Autoelectron Current from Semiconductors—Yu. V. Zubenko, A. K. Klimin and I. L. Sokol’skaya. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1845–1847; December, 1959.) A note is given on field-emission data for W_2C and Ge at variance with other published data [see, *e.g.*, 1922 of 1959 (Gofman, *et al.*)].

537.311.33:621.317.3 2297

A Thermal Shutter Phenomenon in Field-Effect Measurements—N. B. Grover and Y. Goldstein. (*J. Phys. Chem. Solids*, vol. 17, pp. 338–340; January, 1961.) The phenomenon may lead to misinterpretation of field-effect data taken on samples whose temperature differs from that of their surroundings. The nature of the thermal shutter depends only on the mounting of the sample.

537.311.33:621.375.9 2298

New Possibilities of Amplification by Carrier Motion in Semiconductors—E. Groschwitz. (*Z. angew. Phys.*, vol. 12, pp. 370–382 and 400–410; August and September, 1960.) A detailed consideration is given without mathematical treatment, of the theory underlying the transport processes in semiconductors, on the basis of a hypothetical model. 64 references.

537.311.33:621.391.822 2299

On the Influence of Diffusion and Surface Recombination upon the GR Noise Spectrum of Semiconductors—K. S. Champlin. (*Physica*, vol. 26, pp. 751–760; September, 1960.) Several theories of generation-recombination noise in nearly intrinsic semiconductors [see, *e.g.*, 2422 of 1959 (Van Vliet and Van der Ziel)] are critically examined, and it is shown that these theories do not allow for the correlation between Fourier coefficients of different spatial modes of the fluctuations in carrier density. A treatment based on a transmission line analogy is presented and the result examined for the cases when the recombination process is limited by a) volume, b) surface, and c) diffusion.

537.323 2300

Investigation of the Thermoelectric Properties of $CoSb_3$ Compound with Sn, Te and Ni Impurities—B. N. Zobnina and L. D. Dudkin. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1821–1827; December, 1959.)

537.323 2301

Anomalous Thermoelectric Properties of Gadolinium Selenide—R. C. Vickery and H. M Muir. (*Nature*, vol. 190, pp. 336–337; April, 1961.) Anomalies in parameter interrelations of a high *Z*-value GdSe-Gd_2Se_3 composition can be explained in terms of a transport mechanism which is visualized as EM waves of thermal frequency (“thermons”) acting as charge carriers.

537.583 2302

Change in the Work Function of Molybdenum on Deposition of Thin Sodium and Caesium Films—V. N. Lepeshinskaya and V. N. Belogurov. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1806–1812; December, 1959.)

538.221 2303

Threshold Concentration for the Existence of Ferromagnetism in Dilute Alloys—M. Coopersmith and R. Brout. (*J. Phys. Chem. Solids*, vol. 17, pp. 254–258; January, 1961.) See also 817 of 1960 (Brout).

538.221 2304

Magnetization of Iron-Nickel Alloys under Hydrostatic Pressure—J. S. Kouvel and R. H. Wilson. (*J. Appl. Phys.*, vol. 32, pp. 435–441; March, 1961.)

538.221 2305

The Relation between Switching Coefficient and Limiting Frequency of Ferromagnetic Materials—R. Boll. (*Z. angew. Phys.*, vol. 12, pp. 364–370; August, 1960.) The dynamic characteristics of ferromagnetic materials, including thin films, allowing for spin-relaxation and eddy-current losses are investigated. For related work on metal tapes, see 1581 of May. 49 references.

538.221:534.231–8 2306

Movement of Bloch Walls in Ultrasonic Fields—G. Haacke and J. Jaumann. (*Z. angew. Phys.*, vol. 12, pp. 289–297; July, 1960.) Investigations were made on single-crystal Ni in a 1-Mc ultrasonic field. Changes in Bitter patterns are illustrated and the results interpreted.

538.221:537.533.7 2307

Antiparallel Weiss Domains as Biprisms for Electron Interference Effects—H. Boersch, H. Hamish, D. Wohlleben and K. Grohmann. (*Z. Phys.*, vol. 159, pp. 397–404; August, 1960.) The interference effects used in electron-optics investigations of domain patterns (see 2313 below) are studied experimentally; results obtained are in agreement with theory proposed by Aharonov and Bohm (821 of 1960).

538.221:538.213 2308

Locus Curves of Complex Permeability of Thin Tapes—R. Boll. (*Frequenz*, vol. 14, pp. 227–238; July, 1960.) Measurements of permeability on tapes of Ni-Fe and Cu-Fe alloy give results which differ considerably from locus curves based on classical eddy-current theory. These differences are attributable to electron-spin relaxation and resonance effects. See 1581 of May.

538.221:538.613 2309

Limitations of the Magneto-optic Kerr Technique in the Study of Microscopic Magnetic Domain Structures—D. Treves. (*J. Appl. Phys.*, vol. 32, pp. 358–364; March, 1961.)

538.221:539.23 2310

The Interaction of Thin Nickel Films in Ni-Cu Multilayer Systems with Stress-Induced Uniaxial Anisotropy—W. Ruske. (*Mber. dtsch. Akad. Wiss. Berlin*, vol. 2, nos. 3/4, pp. 161–163; 1960.) The coercive force is plotted as a function of Ni-film spacing for Ni-film thicknesses of 275, 575 and 1350 Å. See also 3204 of 1960.

538.221:539.23 2311

The Investigation of Slow Magnetization Processes in Thin Films—W. Hellenthal. (*Naturwiss.*, vol. 47, p. 371; August, 1960.) A note is given on the investigation of magnetic reversal in thin films as a function of time and reverse field strength; typical curves are reproduced.

538.221:539.23:538.614 2312

Microscopic Observation of Straight and Curved Magnetization Structure by means of the Faraday Effect—H. Boersch and M. Lambeck. (*Z. Phys.*, vol. 159, pp. 248–252; July, 1960.) Magnetic domains in thin vapor-deposited Fe films are rendered visible by the method given in 1162 of 1957 (Fowler and Fryer) in conjunction with a high-resolution microscope technique. See also 4324 of 1960 (Boersch, *et al.*).

538.221:539.23:621.385.833 2313

Electron-Optics Investigations of Weiss Domains in Thin Iron Films—H. Boersch, H. Raith and R. Wohlleben. (*Z. Phys.*, vol. 159, pp. 388–396; August, 1960.) A schlieren method [3964 of 1960 (Boersch and Raith)] and a shadow-projection method [*e.g.*, 2085 of 1960 (Fuller and Hale)] are described and results obtained with these methods are illustrated and discussed.

538.221:621.318.134 2314

The Ionic Distribution in the Garnets $Gd_3Al_3Fe_2O_{12}$ and $Y_3Al_3Fe_2O_{12}$—C. E. Miller (*J. Phys. Chem. Solids*, vol. 17, pp. 229–231; January, 1961.)

538.221:621.318.134 2315

On the Structure and Oxygen Content of Copper and Copper-Manganese Ferrite—A. Bergstein and L. Červinka. (*J. Phys. Chem. Solids*, vol. 18, pp. 264–265; February, 1961.)

538.221:621.318.134 2316

Magnetocrystalline Anisotropy of Cobalt-Substituted Manganese Ferrite—J. V. Slonczewski. (*J. Phys. Chem. Solids*, vol. 18, pp. 269–271; February, 1961.)

538.221:621.318.134 2317

Ultra-High-Frequency Properties of Yttrium and Lutecium Ferrite with Garnet-Type Structure—A. G. Gurevich, I. E. Gubler and A. P. Safant’evskiĭ. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1862–1865; December, 1959.) Results of measurements of ferromagnetic resonance, permeability and permittivity are reported.

538.221:621.318.134 2318

Growing Single Crystals of Yttrium Ferrite—A. G. Titova. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1871–1873; December, 1959.) Crystals 12 mm high were obtained using B_2O_3 in the solvent. See 1289 of 1959 (Nielsen and Dearborn).

538.221:621.318.134:538.569.4 2319

Ferromagnetic Resonance in Yttrium Ferrite Single Crystals—A. G. Gurevich and I. E. Gubler. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1847–1850; December, 1959.) A report is given of measurements at 3.25 cm λ on $Y_3Fe_5O_{12}$ single crystals obtained from solution.

538.221:621.318.134:538.569.4 2320

Paramagnetic Resonance of Fe^{3+} in Octahedral and Tetrahedral Sites in Yttrium Gallium Garnet (YGaG) and Anistropy of Yttrium Iron Garnet (YIG)—S. Geschwind. (*Phys. Rev.*, vol. 121, pp. 363–374; January, 1961.)

538.221:621.318.134:538.569.4 2321

Relaxation Mechanisms in Ferromagnetic Resonance—T. Kasuya and R. C. LeCraw. (*Phys. Rev. Lett.*, vol. 6, pp. 223–225; March, 1961.) Recent observations of the relaxation time of spin waves with zero wave vector in Y-Fe garnet are given and theory accounting for the results is outlined.

548.0:538.6 2322

Direction Dependence of Physical Properties in Crystals with Particular Regard to Galvanomagnetic and Thermomagnetic Effects—H. Bross. (*Z. Naturforsch.*, vol. 15a, pp. 859–874; October, 1960.) A method is given for determining the influence of crystal symmetry on the direction dependence of the tensors defining crystal properties. A phenomenological theory of galvanomagnetic and thermomagnetic effects is developed.

MATHEMATICS

517.56:621.372.44 2323

Analytical Representation of the Characteristics of Nonlinear Two-Poles—W. Böning. (*Arch. Elektrotech.*, vol. 45, pp. 265–278; July, 1960.) Nonlinear characteristics are approximated by simple algebraic and transcendental functions. Curves are given for the determination of the requisite coefficients. For related graphical methods, see 3459 of 1956 (Fischer and Moser).

519.281.1:621.391 2324

The Significance of Moments in Time and Frequency Functions—H. Dobesch and H. Sulanke. (*Nachrtech. Z.*, vol. 10, pp. 240–246; June, 1960.) The statistical method of moments is outlined and its application to the determination of transmission characteristics of communication channels is discussed.

MEASUREMENTS AND TEST GEAR

621.317.2:538.566.08]+534.844.1 2325

Reverberation Chamber Technique and Construction of a Large Reverberation Chamber for Electromagnetic Waves—E. Meyer, H. W. Helberg, and S. Vogel. (*Z. angew. Phys.*, vol. 12, pp. 337–346; August, 1960.) The use of reverberation-chamber techniques for the measurement of EM absorption is discussed with reference to absorption measurements in a small echo chamber. The large chamber described (see 1393 of May) is also intended for acoustic measurements.

621.317.3.029.65:621.391.822:621.387 2326

Determination of Noise Temperature of a Gas-Discharge Noise Source for Four-Millimeter Waves—W. Jasinski and G. Hiller. (Proc. IRE, vol. 49, pp. 807–808; April, 1961.) The hot body standard was a heated Si wedge in a waveguide.

621.317.335:621.372.413 2327

Correction Term for Dielectric Measurements with Cavity Resonators—E. S. Hotston. (*J. Sci. Instr.*, vol. 38, pp. 130–131; April, 1961.) "The effect of varying the diameter of a polystyrene disk on the value of its dielectric constant when measured in a resonator of fixed diameter is investigated. Agreement is obtained with results predicted by perturbation theory."

621.317.335.3:538.221:621.318.134 2328

Measurement Equipment for the Determination of the Permeability Tensor and Dielectric Constant of Ferrites at 3000 Mc/s—W. Nowak. (*Hochfrequenz. und Elektroak.*, vol. 69, pp. 83–94; June, 1960.) The principle used is that of measurement inside a circularly polarized cavity resonator; the method of resonator excitation has been simplified.

621.317.341.2.029.4 2329

Nyquist Diagram Tracer for A.F.—A. R. Bailey. (*Electronic Tech.*, vol. 38, pp. 156–159; May, 1961.) Details are given of a laboratory instrument for determining the Nyquist diagram of a circuit in the frequency range 20 cps–20 kc.

621.317.6:621.396.663 2330

Frequency-Independent Measurement of Complex Ratios by means of the Goniometer—H. Fricke. (*Elektrotech. Z., Edn A* vol. 81, pp. 422–427; June, 1960.) The principle of operation of the inductive goniometer is outlined and procedures for determining the ratio of electrical quantities in terms of phase and amplitude are described. A diagram is given for evaluating the ratio when the position and magnitude of the goniometer minimum are known. See also 3613 of 1960.

621.317.7:621.391.822 2331

Sampling Technique for Generating Gaussian Noise—A. J. Rainal. (*Rev. Sci. Instr.*, vol. 32, pp. 327–331; March, 1961.) The noise has a uniform power spectrum from 0.1 cps to 5 kc.

621.317.75:621.374:681.142 2332

Accurate Amplitude Distribution analysed combining Analogue and Digital Logic—T. A. Brubaker and G. A. Korn. (*Rev. Sci. Instr.*, vol. 32, pp. 317–322; March, 1961.) A new precision analyzer yields digital read-out of probability or probability density for random waveforms at low audio frequencies. The use of analog computer techniques permits convenient assembly of such instruments. See 1737 of 1960 (Bickart).

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

551.508.71:537.322.15 2333

An Automatic Dew-Point Hygrometer using Peltier Cooling—P. Gerthsen, J. A. Gilsing, and M. van Tol. (*Philips Tech. Rev.*, vol. 21, pp. 196–200; June, 1960.)

551.510.62:621.372.413 2334

Free-Balloon-Borne Meteorological Refractometer—J. F. Theisen and E. E. Gossard. (*J. Res. NBS*, vol. 65D, pp. 149–154; March and April, 1961.) A 400-Mc refractometer for the investigation of layer-type discontinuities in the troposphere is described.

621.362:621.387 2335

Interpretation of Experimental Characteristics of Cesium Thermionic Converters—E. N. Carabateas, S. D. Pezaris, and G. N. Hatsopoulos. (*J. Appl. Phys.*, vol. 32, pp. 352–358; March, 1961.) Two types of V/T curves can be distinguished in the operation of a Cs converter: collision-free type and sheath type. A method is outlined for obtaining the electron temperature from the sheath-type curve. The emitter work function and temperature can then be estimated.

621.398:681.142 2336

An Equipment for Automatically Processing Time-Multiplexed Telemetry Data—N. Purnell and T. T. Walters. (*J. Brit. IRE*, vol. 21, p. 257–274; March, 1961.) Details are given of the way in which the input signals are derived and the method by which the recordings are made. The equipment produces two forms of output: a) analog graphs on paper film and b) digital records on punched cards. Methods of checking performance are described.

681.175:621.374.3 2337

A Novel Digital Clock—A. Russell. (*Electronic Engrg.*, vol. 33, pp. 150–154; March, 1961.) An indicator of the minute, hour and date, together with a four-figure test number which employs telephone-type uniselectors, is operated by a separate seconds generator. The output is suitable for operating a tape perforator of an electronic typewriter.

PROPAGATION OF WAVES

621.391.812.6.029.45 2338

A Note on Phase Velocity of V.L.F. Radio Waves—J. R. Wait and K. P. Spies. (*J. Geophys. Res.*, vol. 66, pp. 992–993; March, 1961.) The phase velocity is plotted as a function of frequency in the range 8–30 kc for ionospheric heights of 60–100 km using formulas given earlier (4367 of 1960).

621.391.812.6.029.6:537.56 2339

Microwave Propagation through a Magneto plasma—R. L. Phillips, R. G. DeLoch, and D. E. White. (*J. Appl. Phys.*, vol. 32, pp. 551–552; March, 1961.) Plasma sheaths surrounding space vehicles can severely attenuate radio signals. By using a sufficiently strong magnetic field aligned along the direction of propagation, this attenuation can be reduced. The preliminary results of laboratory experiments are given.

621.391.812.61 2340

Weather and Reception Level on a Troposphere Link—Annual and Short-term Correlations—L. G. Abraham, Jr., and J. A. Bradshaw. (*J. Res. NBS*, vol. 65D, pp. 155–156; March and April, 1961.) "The weather parameters suggested by the Booker-Gordon theory (1757 of 1950) are correlated with data from a troposphere link not previously reported. While the correlations over the whole year's weather cycle are high, the short-term correlations practically vanish. The former without the latter lend little support to this theory."

621.391.812.62 2341

Properties of Tropospheric Scattered Fields—N. R. Ortwein, R. U. F. Hopkins, and J. E. Pohl. (Proc. IRE, vol. 49, pp. 788–802; April, 1961.) Scatter tests were made in Southern California in conjunction with meteorological measurements. The observed angular scattering of the received field varies as $\theta^{-14/3}$ which is consistent with turbulent spectra varying as $k^{-5/3}$. Reflections from layers become important in the lower frequency range when the atmosphere begins to stabilize.

621.391.812.621 2342

Graphical Determination of Radio Ray Bending in an Exponential Atmosphere—C. F. Pappas, L. E. Vogler and P. L. Rice. (*J. Res. NBS*, vol. 65D, pp. 175–179; March and April, 1961.) A simplified method is given for calculating the approximate refraction angle as a function of height, for values of surface refractivity ranging from 200 to 450.

621.391.812.621 2343

A Formula for Radio Ray Refraction in an Exponential Atmosphere—G. D. Thayer. (*J. Res. NBS*, vol. 65D, pp. 181–182; March and April, 1961.) The formula is derived by integration of a differential equation, assuming that $(n-1)\times 10^6$ decreases exponentially with height above a smooth spherical earth.

621.391.812.622 2344

The Effect of Multiple Atmospheric Inversions on Tropospheric Radio Propagation—F. H. Northover. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 295–296; April, 1961.) A method of analysis developed for a single inversion is extended to account for the collective effect of several simultaneously occurring inversions.

621.391.812.63 2345

A Theory of Incoherent Scattering of Radio Waves by a Plasma—J. P. Dougherty and D. T. Farley. [*Proc. Roy. Soc.* (*London*), vol. 259, pp. 79–99; November, 1960.] The amplitude and frequency spectrum of the scattered radiation are calculated, making use of a generalized version of Nyquist's noise theorem, and the results are applied to incoherent scatter from the ionosphere. The amplitude is consistent with independent scattering by electrons; the mean Doppler broadening corresponds roughly to the speed of the ions rather than the electrons. The spectral shape is not Gaussian; there is a slight dip at the center frequency. Plasma resonance effects are negligible for frequencies in use at present.

621.391.812.63 2346

The Reflection of Radio Waves from an Iceshelf—W. R. Piggott and L. W. Barclay. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 298–299; April, 1961.) Information concerning the RF properties of the iceshelf is deduced from certain properties of the vertical-incidence ionospheric records made at Halley Bay, Antarctica.

621.391.812.63 2347

Correlation Analysis of the Fading of Radio Waves Reflected Vertically from the Ionosphere—G. F. Fooks and I. L. Jones. (*J. Atmos. Terr. Phys.*, vol. 20, pp. 229–242; April, 1961.) The fading of HF waves, after reflection from the *E* and *F* layers, has been analyzed. Magnetic conditions were quiet. The results, obtained from spaced receivers, give the size and shape of an average irregularity in the ground pattern, the drift velocity and the relative importance of random changes to drift in producing fading.

621.391.812.63 2348

Effect of Antenna Radiation Angles upon H.F. Radio Signals Propagated over Long Distances—W. F. Utlaut. (*J. Res. NBS*, vol. 65D, pp. 167–174; March and April, 1961.) Observations on a 20-Mc CW signal over E-W paths of 6800 km and 8400 km indicate that antennas with very low radiation angle may be advantageous for long-distance reception.

621.391.812.63.029.62 2349

Relationship between f_0E_s and Field Intensity depending on Sporadic-E Propagation in the 50-Mc/s Band—M. Yamaoka. (*J. Radio Res. Labs., Japan*, vol. 7, pp. 599–613; November, 1960.) Transmissions from Okinawa on 49.68 Mc were received at five points in Japan at distances from 1100–2390 km. The field intensity is shown graphically as a function of distance and E_s-layer critical frequency.

621.391.812.631 2350

Polar-Cap Blackout and Auroral-Zone Blackout—Y. Hakura. (*J. Radio Res. Labs., Japan*, vol. 7, pp. 583–597; November, 1960.) A statistical analysis of ten polar-cap events during the I.G.Y. is used to examine the characteristics of the two types of blackout. A detailed examination of the event of July 29, 1958, demonstrates that the two types represent distinct phases; the solar corpuscles responsible are considered.

621.391.812.631:551.510.535(98) 2351

High-Frequency Radio-Wave Blackouts at Medium and High Latitudes during a Solar Cycle—C. Collins, D. H. Jelly, and A. G. Matthews. (*Canad. J. Phys.*, vol. 39, pp. 35–52; January, 1961.) An examination of ionograms for the occurrence over Canada of blackouts correlating with riometer measurements of Type II (auroral) and Type III (polar-cap) absorption events has revealed distinct geographical patterns of blackout occurrence. Study of ionosonde data back to 1949 shows different sunspot cycle variations for the two events.

621.391.814:537.56]+621.372.826 2352

Propagation of Electromagnetic Waves along a Thin Plasma Sheet—J. R. Wait. (*Canad. J. Phys.*, vol. 38, no. 12, pp. 1586–1594; 1960.) "It is shown that a thin ionised sheet will support a trapped surface wave. The effect of a constant and uniform magnetic field is to modify the phase velocity and polarization of the surface wave. The essential features are illustrated by numerical results for selected values of the electron density, collision frequency, and gyro frequency. The effect of locating the plasma sheet near and parallel to a conducting plane is also considered. In this situation other modes of a waveguide type are possible in addition to the surface wave."

621.391.814.029.64+621.372.826 2353

TE Surface Waves Guided by a Dielectric-Covered Metal Plane—D. Morris and A. G. Mungall. (*Canad. J. Phys.*, vol. 38, pp. 1553–1559; December, 1960.) Surface waves were excited over a sand-covered metal plane and the phase velocities of the first three TE modes were determined, as a function of the sand depth, at a frequency of 9300 Mc. The simultaneous existence of two modes with different velocities, predicted theoretically for certain sand depths, was confirmed experimentally. For a report of similar measurements on TM mode surface waves, see 2892 of 1960 (Mungall and Morris).

RECEPTION

621.376.23:621.391.82 2354

Questions of Potential Noise Immunity when the Signal Fades—D. D. Klovskiĭ. [*Radiotekhnika (Moscow)*, vol. 15, pp. 17–25; May, 1960.] Criteria are obtained for coherent and noncoherent detection processes in an ideal receiver in the presence of fluctuating interference and rapid smooth fading. Error probabilities are calculated for different systems.

621.376.23:621.391.822 2355

Further Results on the Detectability of Known Signals in Gaussian Noise—H. C. Martel and H. V. Mathews. (*Bell Sys. Tech. J.*, vol. 40, pp. 423–451; March, 1961.) Solutions are given for a maximum-likelihood detector operating on a finite number of samples of the stimulus, and for an optimum integral operator treating the stimulus as a continuous function.

621.376.23:621.396.962.3 2356

Summary and Comparison of Known Methods for the Detection of Periodic Pulses in the Presence of Noise—D. Haussig. (*Hochfrequenz. und Elektroak.*, vol. 69, pp. 94–103; June, 1960.) The improvement of SNR, *e.g.*, for radar, by integration or cross-correlation methods is discussed. Practical pulse correlator and integrator circuits are proposed; experimental results are illustrated.

621.391.812.3:551.510.535 2357

Analysis of Random Fading Records—S. R. Khastgir and R. N. Singh. (*Indian J. Phys.*, vol. 34, pp. 527–530; November, 1960.) An analysis is given of experimental results obtained using three spaced receivers on a frequency of 3.8 Mc. See also 3859 of 1960.

621.391.823:621.396.669 2358

Interference Suppression of PTT Motor Vehicles—E. Meister. (*Tech. Mitt. PTT*, vol. 38, pp. 271–277; August, 1960. In German and French.) An analysis is given of the results of tests on motor vehicles of the Swiss Post Office fitted with interference-suppression devices, to assess the effectiveness of the methods of suppression adopted and any influence they may have on the running efficiency of the vehicle. See also 1627 of May (Walter).

621.391.823:621.396.669 2359

Interference Suppression of Vehicles with Petrol Engines—(*Tech. Mitt. PTT* , vol. 38, pp. 314–315; September, 1960. In German, French, and Italian.) A suppression method and installation instructions are given. See also 2358.

621.396.62 2360

The Effectiveness of Methods of Increasing the Dynamic Range of a Panoramic Radio Receiver—N. I. Svetlov. [*Radiotekhnika (Moscow)*, vol. 15, pp. 29–32; May, 1960.] Experiments show that an automatically re-aligned filter comprising two reactance tubes in a bandpass circuit not only decreases crosstalk but reduces nonlinear distortion.

621.396.62:523.164.32 2361

Voltage-Tuned Swept-Frequency Receiver—J. J. Riihimaa. (*Rev. Sci. Instr.*, vol. 32, pp. 289–291; March, 1961.) A voltage-tuned solar spectrum analyzer, employing Si tuning capacitors, has been developed. It covers the range 15–30 Mc at sweep rates up to 10 per second.

621.396.62.029.62 2362

Fundamental Requirements for a Good F.M. V.H.F. Broadcast Receiver—E. Wey. (*Tech. Mitt. PTT*, vol. 38, pp. 257–271; August, 1960. In German and French.) A summary touching on sensitivity, selectivity and quality requirements and dealing with the measurement and reduction of interference is given.

621.396.62.029.62 2363

A New Swiss Radio Receiver with V.H.F. Stage, conforming to PTT (Swiss Post Office) Specifications—W. Strohschneider. (*Tech. Mitt. PTT*, vol. 38, pp. 304–311; September, 1960. In German and French.) Circuit diagram and design details are given. See also 2362.

621.396.62.029.64:523.164 2364

A Low-Noise *X*-Band Radiometer using Maser—J. J. Cook, L. G. Cross, M. E. Bair and R. W. Terhune. (PROC. IRE, vol. 49, pp. 768–778; April, 1961.) A reflection cavity maser with voltage-gain × bandwidth products up to 300 Mc at 4.2°K is used. The gain instability is less than 1 per cent up to 10 minutes and 2 per cent up to 30 minutes. A noise factor of 0.6 db (43°K) has been obtained with rms noise fluctuations of 0.01°K and 0.007°K for integration times of 12 and 43 seconds, respectively.

STATIONS AND COMMUNICATION SYSTEMS

621.376.5 2365

Pulse Transmission by A.M., F.M. and P.M. in the Presence of Phase Distortion—E. D. Sunde. (*Bell Sys. Tech. J.*, vol. 40, pp. 353–422; March, 1961.) Performance in pulse transmission systems using various carrier modulation and detection methods is formulated in terms of a common basic function known as the carrier pulse transmission characteristic. A comprehensive theoretical evaluation of transmission impairment caused by various types of phase and envelope delay distortion is made.

621.391.64:621.376.223 2366

Solid-State Modulators for Infrared Communications—P. W. Kruse and L. D. McGlauchlin. (*Electronics*, vol. 34, pp. 177–181; March, 1961.) Free carrier absorption in a semiconductor may be used to modulate a beam of infrared radiation. Ge modulator characteristics and circuit details of a transmitter/receiver with a range of greater than one mile are given.

621.396.215 2367

A Comparison between Alternative H.F. Telegraph Systems—W. Lyons, J. V. Beard, and A. J. Wheeldon. (*Point to Point Telecommun.*, vol. 5, pp. 11–17; February, 1961.) Comment on 1026 of March and authors' reply are given.

621.396.4:621.376.23 2368

Suppressed-Carrier Double-Sideband Systems—G. W. Short. (*Wireless World*, vol. 67, pp. 242–243; May, 1961.) Summaries receiving techniques and system advantages and difficulties are given.

621.396.43:[523.3+551.507.362.2 2369

Use of Moon or Satellite Relays for Global Communications—L. P. Yeh. (*Commun. and Electronics*, no. 51, pp. 607–615; November, 1960.) Results of the major moon-echo experiments are summarized and compared in tabular form. General conclusions regarding the use of the moon as a passive and an active relay are discussed in relation to the performances expected of similar satellite relays.

621.396.43:621.391.812.826 2370

Analysis and Detection of Echo Signals on Microwave Radio Paths—G. E. Rosman. [*Proc. IRE* (*Australia*), vol. 21, pp. 810–820; November, 1960.] The permissible echo parameters for a 600-channel circuit and the effects of antenna directivity for a 40-mile path at 4 Gc are assessed.

621.396.65 2371

The Radio Telephone Terminal—B. W. Bardwell. (*Point to Point Telecommun.*, vol. 5, pp. 28–54; February, 1961.) Deals with the functions of the terminal, especially with reference to independent-sideband working, are given.

621.396.65:621.391.812.624 2372

A Tropospheric Scatter Link over a 200 Mile Path—G. L. Grisdale and D. A. Paynter. (*Point to Point Telecommun.*, vol. 5, pp. 34–59; October, 1960.) Operating experience with the 1958–1959 Start Point–Galleywood link showed that, using diversity reception, communication with a 24-telephone channel system on 858 Mc was reliable for 99 per cent of the time.

621.396.65:621.398 2373

Telemetering and Remote Control over Radio Links—S. Skoumal. (*Point to Point Telecommun.*, vol. 5, pp. 15–33; October, 1960.) A discussion of different methods and systems is given.

621.396.932 2374

Use and Service Time of Short Waves: Predictions for the Spanish Sea Routes—R. Gea Sacasa. [*Rev. Telecommun.* (*Madrid*), vol. 16, pp. 2–16; September, 1960.] See also 1779 of 1960.

621.396.934:551.507.362.2 2375

New Satellite Tracking Station in Great Britain—(*J. Brit. IRE*, vol. 21, pp. 150–152; February, 1961.) A general description of the 136-Mc Minitrack radio interferometer is given. For a similar account, see *Electronic Engrg.*, vol. 33, pp. 160–161; March, 1961.

621.396.945 2376

Radio-Wave Propagation in the Earth's Crust—H. A. Wheeler. (*J. Res. NBS*, vol. 65D, pp. 189–191; March and April, 1961.) A note is given on the presence of a "waveguide," in the earth's crust, composed of low-conductivity basement rock, and its application to VLF communication problems.

621.396.946:621.391.63 2377

Interstellar and Interplanetary Communication by Optical Maser—R. N. Schwartz and C. H. Townes. (*Nature*, vol. 190, pp. 205–208; April, 1961.) An examination is given of the possibility of transmitting an optical beam from a planet associated with a star at a sufficiently high power level to establish communications with the earth.

SUBSIDIARY APPARATUS

621.3.017.7:621.373.421.13 2378

The Change-of-State Crystal Oven—D. J. Fewings. (*J. Brit. IRE*, vol. 21, pp. 137–142; February, 1961.) The action of the oven depends upon the constancy of the melting point of crystalline material and the thermal ballasting due to the latent heat of fusion. An oven of this type can restrict the frequency shift to 2.8 parts in 10^8 for a temperature change of 10°C.

621.311.68:621.316.726 2379

Precise Frequency Control for a Rotary Convertor—M. J. Tucker. (*Electronic Engrg.*, vol. 33, pp. 240–241; April, 1961.) "The Royal Research Ship 'Discovery II' has been provided with a 50 c/s power supply whose frequency is precise to approximately 1 part in 10^5, by locking the phase of a small rotary convertor to that of a 50 c/s reference signal derived from a quartz-crystal oscillator."

621.311.69:621.383.5 2380

Detailed Balance Limit of Efficiency of *p-n* Junction Solar Cells—W. Shockley and H. J. Queisser. (*J. Appl. Phys.*, vol. 32, pp. 510–519; March, 1961.) A theoretical upper limit for efficiency is deduced assuming that recombination is entirely radiative. Maximum efficiencies of 30 per cent are found.

621.311.69:621.383.5 2381

Characteristics of a High Solar Conversion Efficiency Gallium Arsenide *p-n* Junction—E. G. Bylander, A. J. Hodges, and J. A. Roberts. (*J. Opt. Soc. Am.*, vol. 50, pp. 983–985; October, 1960.) Spectral emissivity and response data are given for GaAs photocells which have an open-circuit voltage of about 0.85 v and short-circuit current density 13–15 ma/cm^2.

621.314.1:621.382.3 2382

The Choice and Design of D.C. Convertors—J. S. Bell and P. G. Wright. (*Electronic Engrg.*, vol. 33, pp. 226–231; April, 1961.) The design of single- and two-transformer converters using transistors is discussed and their performances are compared. Design steps are indicated and two practical examples are given.

621.314.631 2383

Power Semiconductor Ratings under Transient and Intermittent Load—F. W. Gutzwiller and T. P. Sylvan. (*Commun. and Electronics*, no. 52, pp. 699–706; January, 1961. Discussion.) Methods of calculating maximum allowable dissipation are discussed, with examples.

621.314.63 2384

Transient Thermal Impedance of Semiconductor Devices—E. J. Diebold and W. Luft. (*Commun. and Electronics*, no. 52, pp. 719–726; January, 1961.)

621.316.72:621–52 2385

A New D.C. Level Control for Adaptive Systems—R. A. Johnson and J. D. Hill. (*Electronic Engrg.*, vol. 33, pp. 242–244; April, 1961.) A novel electronic circuit is described and analyzed which maintains the potential drop across a load constant to within a fraction of one per cent while permitting the dc level of the load to be varied through a wide range. The circuit requires only standard-tolerance electronic components, and high precision is obtained by an error compensation technique.

TELEVISION AND PHOTOTELEGRAPHY

621.397.13 2386

Television Standards—H. Dobesch. (*Radio und Fernsehen*, vol. 9, pp. 447–449; July, 1960.) Comparative data tables and waveform diagrams are given for the seven monochrome television systems in present use.

621.397.132 2387

Distortion due to System and Transmission Faults in Colour Television based on the N.T.S.C. System—H. Schönfelder. (*Rundfunktech. Mitt.*, vol. 4, pp. 158–172; August, 1960.) Faults likely to occur in the NTSC system are reviewed; their effect on picture quality is shown to be small in most cases.

621.397.132 2388

Critical Consideration of the "Henri de France" Colour Television System and a Modification with Better Vertical Resolution—P. Neidhardt. (*Nachrtech Z.*, vol. 10, pp. 286–290; July, 1960.) A comparison is given of the "Henri de France" system (*e.g.*, 3660 of 1960) and the NTSC system, with suggestions for improving the former.

621.397.334 2389

Modern Aspects of the Design of Colour Television Film Scanners with Flying-Spot Tubes—P. Neidhardt. (*Elektron. Rundschau*, vol. 14, pp. 307–313; August, 1960.) A review is given of the optical and mechanical problems involved in the design of flying-spot scanners with details of some of the solutions adopted in various systems.

621.397.334 2390

Optical Problems with Flying-Spot Colour Scanners—G. Emmrich. (*Nachrtech. Z.*, vol. 10, pp. 290–295; July, 1960.) Difficulties of optical system design are discussed with reference to existing types of scanner.

621.397.334 2391

Experiences with a Colour-Television Transparency Scanner—M. Samlenski. (*Nachrtech. Z.*, vol. 10, pp. 295–298; July, 1960. Plate.) Design problems of a flying-spot scanner for color transparencies are discussed.

621.397.334 2392

Prospects for Colour Picture Tubes with only One Electron-Beam System in Comparison with the Triple-Beam Mask-Type Tubes—I. Bornemann. (*Nachrtech. Z.*, vol. 10, pp. 305–309; July, 1960.)

621.397.612 2393

New Problems in the Design of Video Switching Installations—L. W. Germany. (*Rundfunktech. Mitt.*, vol. 4, pp. 145–152; August, 1960.) The factors governing the choice of a television studio master control system are reviewed and various methods of switching and program control are described, including a system in which timing is controlled automatically by punched paper tape.

621.397.62:621.382.3 2394

The Transistorized TV Receiver using a New Horizontal Deflection System—T. Miura and K. Mano. (*Sci. Repts. Res. Inst. Tohoku Univ., Ser. B.*, vol. 12, no. 1, pp. 41–55; 1960.) The horizontal deflection system described uses six power transistors in a series/parallel combination in the output stage. Sufficient output is provided to operate a 17-inch 90° tube.

621.397.62:621.396.67 2395

The Influence of Mismatch on Television Picture Quality in Single- and Common-Aerial Installations—A. Köhler. [*Funk-technik* (*Berlin*), vol. 15, pp. 604 607; September, 1960.] Attenuation and reflection effects are considered and practical aspects of installation design minimizing mismatch are discussed.

621.397.621:621.385.832 2396

A Low-Power Cathode for Television Picture Tubes—H. E. Smithgall. (*Sylvania Technologist*, vol. 13, pp. 118–121; October, 1960.) A heater-cathode assembly with a diameter of 0.05 inch, thickness of 0.011 inch and rated power of 0.21 w, is described. It is rugged mechanically, operable over a range of 1.2–1.6 v, and has a heating time of 10 seconds for stable operation.

621.397.7–182.3 2397

Television Outside-Broadcasting by the Radio-diffusion-Television Française—(*E.B.U. Rev.*, no. 62A, pp. 150–164; August, 1960.) Light-weight equipment is described and methods of outside-broadcast operation are mentioned.

621.397.74 2398

Requirements for and Measurements on Long-Distance Television Links—J. Müller.

(*Nachrtech. Z.*, vol. 13, pp. 327–334; July, 1960.) CCIR recommendations are outlined and results are given of measurements based on these, which were made on a 4-Gc radio link over 2000 km. Tests to assess the suitability of the system for NTSC color television are proposed.

621.397.74(485) 2399
The Development of the Television Network in Sweden—T. Rosenlund. (*E.B.U. Rev.*, no. 62A, pp. 162–165; August, 1960.)

TUBES AND THERMIONICS

621.382.2/.3:061.3 2400
International Symposium on Semiconductor Devices—A. V. J. Martin. (*Électronique et Automatisme*, no. 9, pp. 145–150; 168; March-April, 1961.) A report of a UNESCO symposium held in Paris, February 20–25, 1961, is given. The titles of all papers presented are given and selected papers are reviewed.

621.382.23 2401
Effect of Fluctuations in Density on the Esaki Effect—D. G. Dow. (Proc. IRE, vol. 49, p. 837; April, 1961.) Some theoretical expressions are developed and numerically evaluated to assess the extent of spatial fluctuations of tunnel current to be expected in an Esaki diode.

621.382.23 2402
Tunnel-Diode Large-Signal Simulation Study—S. B. Geller and P. A. Mantek. (Proc. IRE, vol. 49, pp. 803–804; April, 1961.) An equivalent circuit is investigated for dynamic response using both analog simulation and graphical analysis.

621.382.23 2403
Oscillations in the Longitudinal Tunnel Current of Tunnel Diodes—R. R. Haering and P. B. Miller. (*Phys. Rev. Lett.*, vol. 6, pp. 269–271; March, 1961.) Small fluctuations in the electron term level are proposed to explain observed oscillations in tunnel current in a longitudinal magnetic field [1239 of April (Chynoweth, *et al.*)].

621.382.23 2404
Influence of the State of the Surface on the Breakdown Voltage of Alloy-Type Silicon Diodes—Zh. I. Alferov and E. V. Silina. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1878–1879; December, 1959.) A note on the change in breakdown voltage when the surface states are cyclically reproduced is given. Typical *I-V* characteristics are shown for air, vacuum and after heating in vacuum.

621.382.23 2405
'Breakdown' of Alloy-Type Silicon Diodes in the Forward Direction—Z. I. Alferov and É. A. Yarv. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1879–1882; December, 1959.) The absence of any effect of illumination or magnetic field on the breakdown voltage, and other experimental data indicate that breakdown is due to leakage effects of a nonohmic character.

621.382.23:621.317.33 2406
Measurement of Tunnel-Diode Negative Resistance—C. D. Todd. (*Rev. Sci. Instr.*, vol. 32, pp. 338–342; March, 1961.) Several methods are presented, including an accurate null technique. Test equipment which will allow stabilization of most tunnel diodes is described.

621.382.23:621.372.44 2407
Three-Layer Negative-Resistance and Inductive Semiconductor Diodes—W. W. Gärtner and M. Schuller. (Proc. IRE , vol. 49, pp. 754–767; April, 1961.) Combinations of effects in three-layer semiconductor diodes may lead to many negative-resistance and inductive devices with applications to microwave circuit design. The theory underlying these devices and the problems involved are discussed.

621.382.23:621.372.44 2408
Capacitance Coefficients for Varactor Diodes—R. D. Weglein and S. Sensiper. (Proc. IRE, vol. 49, p. 810; April, 1961.)

621.382.23:621.372.44 2409
Comparative Figures of Merit for Available Varactor Diodes—K. Siegel. (Proc. IRE, vol. 49, pp. 809–810; April, 1961.)

621.382.23:621.372.44 2410
Parametric Diodes: Design and Fabrication—D. B. Day. (*J. Brit. IRE*, vol. 21, pp. 283–286; March, 1961.) Short notes are given on theory, design and fabrication of diodes with cutoff frequencies in the region of 50 Gc.

621.382.23:621.373.029.631.64 2411
Tunnel-Diode Microwave Oscillators—F. Sterzer and D. E. Nelson. (Proc. IRE, vol. 49, pp. 744–753; April, 1961.) Diodes working between 610 and 8350 Mc are described, with power outputs ranging from 0.01 mw at 7130 Mc to 10 mw at 610 Mc. Problems relating to frequency, power output and waveform are treated analytically.

621.382.23:621.375.9 2412
A Broad-Band Tunnel-Diode Amplifier—Moody and Wacker. (See 2141.)

621.382.23:621.375.9 2413
A Noise Investigation of Tunnel-Diode Microwave Amplifiers—A. Yariv and J. S. Cook. (Proc. IRE, vol. 49, pp. 739–743; April, 1961.) The agreement between the measured noise figure and the theoretical results is an indirect check on the existence of full shot noise in Ge tunnel diodes at microwave frequencies. The approach to the limiting noise temperature in an amplifier by the use of appropriate circuits is discussed.

621.382.23:621.376.23 2414
The Tunnel Diode as a Highly Sensitive Microwave Detector—M. D. Montgomery. (Proc. IRE, vol. 49, pp. 826–827; April, 1961.) Good sensitivity has been obtained by biasing the diode near oscillation and operating it as a square-law detector . Experimental results are quoted at frequencies near 1 Gc.

621.382.3 2415
Transistor Internal Parameters for Small-Signal Representation—R. L. Pritchard, J. B. Angell, R. B. Adler, J. M. Early and W. M. Webster. (Proc. IRE, vol. 49, pp. 725–738; April, 1961.) A summary report is given of a working group which studied a) the parameters which emphasize the physical mechanism of transistors, b) symbols for these parameters and c) the relation between these parameters and those employed in circuit analysis and design. 35 references.

621.382.3.012.8 2416
A Complete Transistor Equivalent Circuit—R. H. Beeson. (Proc. IRE, vol. 49, pp. 825–826; April, 1961.] The circuit given is implicit in the analysis of Ebers and Moll (884 of 1955).

621.382.333 2417
Measurement of the Number of Impurities in the Base Layer of a Transistor—H. K. Gummel. (Proc. IRE, vol. 49, p. 834; April, 1961.) The collector current is measured as a function of emitter-to-base voltage. N_B is then calculated from the simple expression given.

621.382.333 2418
Silicon Surface Alloy Transistors for High-Frequency Switching and Chopper-Amplifier Applications—P. A. Charman. (*J. Brit. IRE*, vol. 21, pp. 201–204; February, 1961.)

621.382.333.33 2419
The Dependence of Current Gain of Drift Transistors on Emitter Current—G. Schwabe. (*Z. angew. Phys.*, vol. 12, pp. 314–320; July, 1960.) The differences in the gain characteristics of drift and diffusion-type transistors are discussed; at high emitter currents their characteristics become similar.

621.383.5 2420
GaAs, a Sensitive Photodiode for the Visible—G. Lucovsky and P. H. Cholet. (*J. Opt. Soc. Am.*, vol. 50, pp. 979–983; October, 1960.) Highly sensitive photodiodes have been formed by diffusion of Cd and Zn in *n*-type GaAs. Operated as photovoltaic detectors, the diodes have half-sensitivity points at 9100 and 5600 Å and a dynamic impedance of the order of 1 mΩ with time constant 1 ms. Certain diodes are equally sensitive when operated in the photoconductive mode.

621.385.032.213.23 2421
On the Electron Emission from Oxide-Coated Cathode subject to Strong Electric Field—C. Shibata. (*J. Phys. Soc. Japan*, vol. 16, pp. 51–61; January, 1961.) Deviation of emission from the Schottky value is explained by an avalanche effect in the oxide layer. Calculated and measured values are compared.

621.385.032.213.23 2422
Oxide-Cathode Emission under Positive-Ion Bombardment—I. A. Abroyan. (*Fiz. Tverdogo Tela*, vol. 1, pp. 1854–1856; December, 1959.) Commercial oxide cathodes 5 mm in diameter were bombarded with potassium ions of energy 1–10 kev and hydrogen ions of 5–70 kev. The increase in emission current from the cathode under postassium-ion bombardment reached values of 1000 to 5000 electrons per incident ion.

621.385.032.213.23 2423
Application of Shot-Noise Techniques to the Study of Emission in Oxide Cathodes—B. Wolk. (*Sylvania Technologist*, vol. 13, pp. 129–136; October, 1960.)

621.385.6 2424
Small-Signal Space-Charge Density in Drifting Ion-Neutralized Rectilinear-Flow Beams Immersed in an Axial Magnetic Field of Finite Magnitude—V. Bevc. (Proc. IRE, vol. 49, pp. 815–816; April, 1961.)

621.385.6:621.375.9:621.372.44 2425
Behavior of Thermal Noise and Beam Noise in a Quadrupole Amplifier—R. Adler and G. Wade. (Proc. IRE, vol. 49, p. 802; April, 1961.)

621.385.63 2426
RF Focusing of an Electron Stream—C. K. Birdsall, G. W. Rayfield, E. Sugata, M. Terada, and K. Ura. (Proc. IRE, vol. 49, pp. 819–821; April, 1961.) Attention is drawn to an error in 3330 of 1960 and further comments by Sugata, *et al.*, are included.

621.385.632 2427
Matching between Travelling-Wave-Tube Helix and Waveguide—T. Unotoro. (*Rev. Elec. Commun. Lab., Japan*, vol. 8, pp. 560–572; November–December, 1960.) The optimum dimensions of the coupling circuit for mass-produced tubes are determined by a statistically designed series of measurements.

621.385.632.1 2428
Experiments on a Series of *S*-Band Crestatrons—J. E. Rowe, G. T. Konrad, and H. W. Krage. (*Commun. and Electronics*, no. 52, pp. 828–833; January, 1961.) The operation of this device is discussed and experimental data are given for fixed length and variable-length tubes.

The tube is small and operates at high efficiency. See 2427 of 1959 (Rowe).

621.385.832:621.397.62 2429

Some Electron Trajectories in a Nonuniform Magnetic Field—T. N. Chin. (Proc. IRE, vol. 49, pp. 832–833; April, 1961.) The nonuniformity is introduced to improve thin cathode-ray tube deflection sensitivity and reduce the width of the scan-producing electromagnet. The equations of the resulting trajectories are derived.

621.385.832:621.397.621 2430

A Low-Power Cathode for Television Picture Tubes—Smithgall. (See 2396.)

621.387:621.362 2431

Interpretation of Experimental Characteristics of Cesium Thermionic Converters—Carabateas, Pezaris, and Hatsopoulos. (See 2335.)

MISCELLANEOUS

061.6:621.37/.39 2432

Report of the United States of America National Committee to the XIII General Assembly of the International Scientific Radio Union, London, England, September 5 to 15, 1960—(*J. Res. NBS*, vol. 64D, pp. i–v and 591–767; November–December, 1960.) A brief report is given by each Commission of the progress made in its field during the period 1957–1960.

538.569.2.047 2433

Some Technical Aspects of Microwave Radiation Hazards—W. W. Mumford. (Proc. IRE, vol. 49, pp. 427–447; February, 1961.) A review of information available and of the safety measures adopted by Bell Laboratories is given. A recommended method of calculating power densities is derived and some commercial power-density meters are described. 78 references.

621.3(083.7) 2434

Supplement to I.R.E. Standards on Graphical Symbols for Electrical Diagrams, 1954—(Proc. IRE, vol. 49, pp. 467–468; February, 1961.) Standard 54 IRE 21.S1.

621.37/.38].029.6 2435

Recent Developments in Microwave Physics—H. Severin. (*Naturwiss.*, vol. 47, pp. 217–221; May, 1960.) A review dealing particularly with improved ferromagnetic and ferrimagnetic materials and semiconductors, and their applications in new microwave devices is presented.

621.38.004.6 2436

Reliability of Electronic Equipment—H. J. Fründt. (*Elektrochem. Z.*, Edn A, vol. 81, pp. 338–341; April, 1960.) A method of determining the operational reliability of complex equipment on the basis of the known failure rates of its components is described.

621.39(047.1) 2437

Communication Engineering and Radiolocation—(*VDI Z.*, vol 103, pp. 189–203; February, 1961.)A progress report covering recent developments, with references mainly to German literature is given. The following sections are surveyed:

a) **Telecommunications**—W. Althans, pp. 189–191.

b) **Sound Broadcasting and Television**—K. Müller, pp. 191–194. 99 references.

c) **Radar and Radio Navigation**—W. Stanner, pp. 195–196.

d) **Electroacoustics**—H. Harz, pp. 197–200. 64 references.

e) **High-Frequency Measurements**—A. Egger, pp. 201–203. 65 references.

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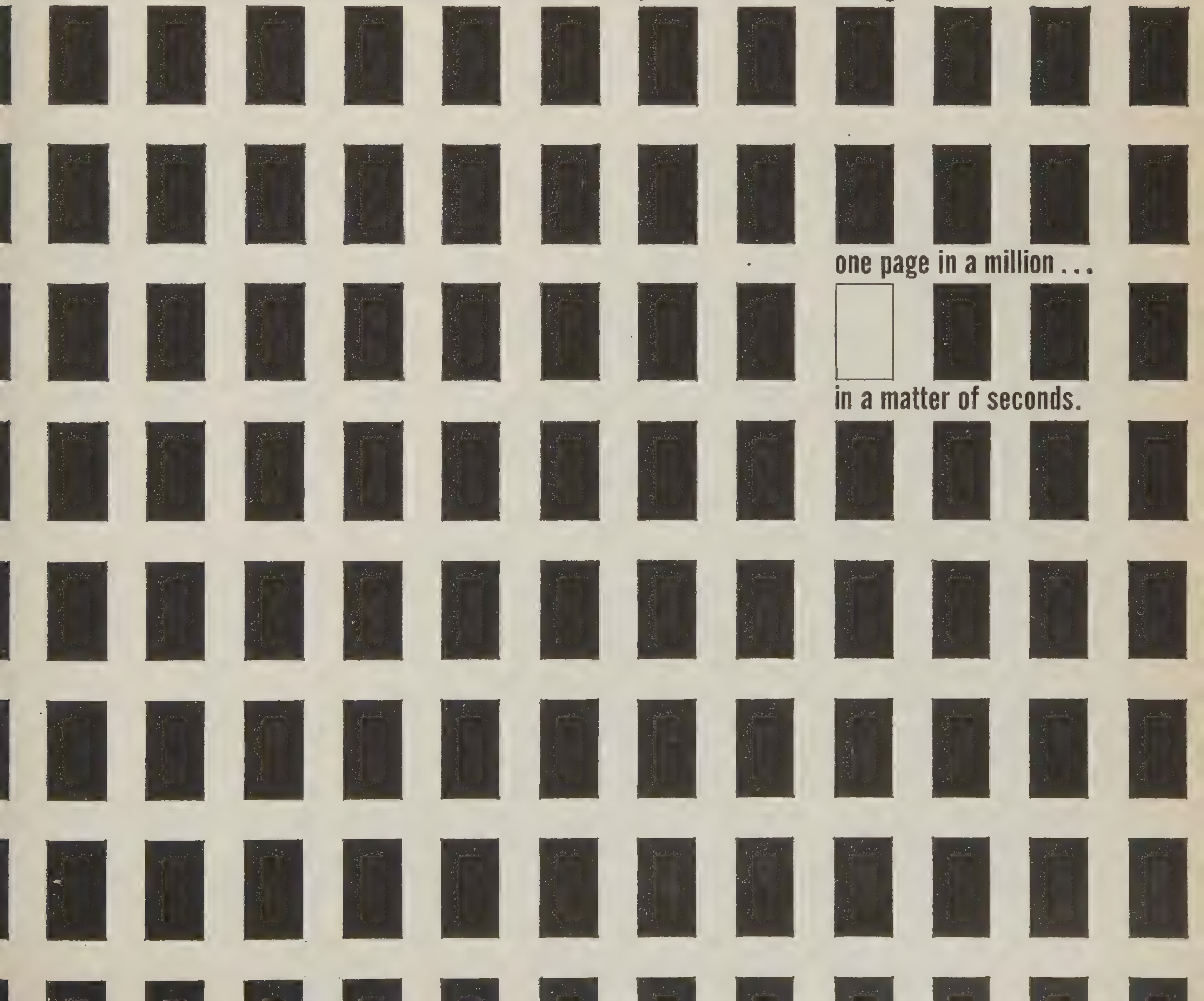
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EXHIBITORS' LIST

The following is a list of exhibitors at the annual Western Electronic Show and Convention, being held this year at the Cow Palace and Fairmont Hotel, San Francisco, California, on August 22 through 25. For complete list of technical sessions, see page 20A.

ACDC Electronics, Inc.	105
ACF Electronics Div., ACF Industries, Inc.	2820-2822
ADC, Inc.	4218
AEL, Inc.	1209
AMP, Inc.	517-521 & 417
A. P. M. Corporation	2614
Ace Electronics Associates, Inc.	3110
Ace Engineering & Machine Co., Inc.	1311
Acoustica Associates, Inc.	1407-1409
Adage, Inc.	3610
Aero Bolt & Screw Co., Inc.	5130
Airborne Instruments Laboratory, Div. of Cutler-Hammer, Inc.	2118-2119
Airpax Electronics, Inc.	1716-1718
Aladdin Electronics	2615
Alden Electronic & Impulse Recording Equipment Co., Inc.	4314
Alden Products Company	4219
Alford Manufacturing Co.	1005-1007
Alfred Electronics	1412
Alite Div., U. S. Stoneware Co.	1202-1204
Allen-Bradley Company	1515-1516
Allen-Jones, Inc.	1216
Allied Chemical Corp., General Chemical Div.	4706
Alpha Metals, Inc.	4924
Alpha Wire Corp.	4732-4734
Amco Engineering Co.	4731-4733
American Bosch Arma Corp.	4126-4128
American Electrical Heater Co.	5131
American-Marietta Company	4523
American Optical Company	3707-3713
American Super-Temperature Wires, Inc.	4928-4930
American Systems, Inc.	4403
Amperex Electronic Corporation	3301-3303
Ampex Computer Products Company	1101-1105
Ampex Instrumentation Products Co.	1107-1113
Amphenol-Borg Electronics Corp.	3411-3421
Anaconda Wire & Cable Co.	4720
Analab Instrument Corp.	1218
Anchor Plating & Tinning Co., Inc.	5015
Andrew Corporation	1821
Anetsberger Brothers, Inc.	4829
Antenna & Radome Research Associates	4221
Antlab, Inc.	4116
Applied Development Corp.	4507
Applied Physics Corp.	4308
Arco Electronics, Inc.	2610
Arnold Engineering Company	1905-1909
Artos Engineering Co.	4721
Assembly Products, Inc.	3401-3403
Associated American Winding Machinery, Inc.	4628
Astro Dynamics, Inc.	712
Astro-Science Corp.	121
Astrodata, Inc.	2417-2419
Astron Corporation	3221
Atlantis Electronics Corp.	4508
Atohm Electronics	3506-3508
Augat Brothers, Inc.	1021
Auto Data	1118
Automatic Electric Sales Corp.	2201-2203
Automatic Metal Products Corp.	2514
Automation Development Corp.	1805
Autonetics, Div. of North American Aviation, Inc.	1418-1420
Autotronics, Inc.	204
Avco Corporation	1326-1328
Aviel Electronics, Inc.	319
Avnet Corporation	403-405
B & K Manufacturing Co.	4122
Babcock Electronics Corp.	310
Babcock Relays, Inc.	312
Baird-Atomic, Inc.	3720-3722
Ballantine Laboratories, Inc.	2501
Barber-Colman Company	3601-3603
Barnes Engineering Co.	1308-1309
Beattie-Coleman, Inc.	2426-2428
Beckman Instruments, Inc.	2001-2004
Behlman Engineering Co.	3114-3116
Belden Manufacturing Co.	4612-4614
Bell Company, Arvin	4516
Bendix Corporation	2902-2908, 2605-2606, 2801-2807
Bird Electronic Corp.	1922-1924
Birtcher Corporation	1910
Blaw-Knox Company	4226-4228
Bliley Electric Company	1914
Blue M Electric Company	5112-5114
Boesch Mfg. Div., Waltham Precision Instrument Co., Inc.	4616
Bomac Laboratories, Inc.	2015-2017
Boonton Electronics Corp.	2412-2414
Boonton Radio Corp.	2018-2020
Borg-Wagner Corporation	2717-2721
Bourns, Inc.	3102-3104
Bowmar Instrument Corp.	2922
Bracamonte & Company, R. M.	4904
Bradley Semiconductor Corp.	1305
Brady Company, W. H.	4831-4833
Brand-Rex Div., William, American Enka Corp.	4604
Branson Corp.	1018
Branson Instruments, Inc.	4920
Bristol Company	3316-3318
Buchanan Electrical Products Corp.	421
Buckbee Mears Company	4728
Bud Radio, Inc.	304
Budd-Stanley Co., Inc.	1217
Burgess Battery Company	1719
Burndy Corporation	2601-2603
Burr-Brown Research Corp.	3320
Burroughs Corporation	2507-2509
Bussmann Mfg. Div., McGraw-Edison Co.	1813
CBS Electronics	2903-2905
C I Industries	4729
C & K Components, Inc.	2916
Cadre Industries Corp.	1207
Cain & Company	108
Calibration Standards Corp.	4124
California Magnetic Control Corp.	106
California Technical Industries, Div. of Textron, Inc.	303-305
Camblock Corporation	4412
Cambridge Thermionic Corp.	1715
Camloc Fastener Corp.	4812-4814
Cannon Electric Company	2302-2306
Capitol Radio Engineering Institute	P-4
Carter Company, J. C.	111
Centralab, Electronics Div. of Globe Union	920-922
Ceramaseal, Inc.	4227
Chalco Engineering Corp.	2703
Chemprint Corporation	4225
Chicago Dynamic Industries, Inc.	1112
Chicago Standard Transformer Corp.	1517
Chicago Telephone of California, Inc.	3706
Chilton Company, "Aircraft & Missiles"	P-17
Chilton Company, "Electronic Industries"	P-11
Christie Electric Corp.	2901
Cinch Manufacturing Co.	404-410
Clare & Company, C. P.	1009-1011
Clarostat Mfg. Co., Inc.	1714
Clevite Corporation	809-815
Coast Pro-Seal Mfg. Co.	5014
Cobehn, Inc.	4824
Cohn Corporation, Sigmund	4715
Coil Winding Equipment Co.	5005-5006
Coleman Electronics, Inc.	2418-2424
Collins Electronics, Inc.	1110
Collins Radio Company	1301-1302
Comar Electric Company	3010
Cominco Products, Inc.	4530
Communications Control Corp.	4517
Computer Control Co., Inc.	819-821
Computer-Measurements Co.	1524-1525
Conrad, Inc.	912
Consolidated Avionics Corp.	1120
Consolidated Electrodynamics Corp.	3708-3710
Control Switch Div., Controls Co. of America	1319-1321
Cool Fin Corporation	414
Coors Porcelain Company	4832-4834
Cornell-Dubilier Electronics, Div. of Federal Pacific Electric Co.	3405-3409
Corning Glass Works	1820-1822
Costello & Company	1307
Craig Corporation	1315
Cramer Controls Corp.	4419
Crystalonics, Inc.	3725
Cubic Corporation	3001-3003
Curtiss Wright Corporation	210-214
Dage Electric Company, Inc.	2918
Dale Electronics, Inc.	2122-2123
Dalmo Victor Company	4234
Data-Stor Div., Cook Electric Company	4223
Datex Corporation	1015
Daven Company	3002
Daystrom, Inc.	2907-2921
Decker Corporation	4522-4524
DeJur-Amsco Corporation	1919-1921
Delco Radio Div., General Motors Corp.	2518-2520
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Delta-F, Inc.	4503

(Continued on page 95A)

DESIGN WITH ARNOLD 6T CORES . . .

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Arnold 6T tape cores (aluminum-cased and hermetically-sealed) offer you three very important design advantages. *One:* Maximum compactness, comparable to or exceeding that previously offered only by plastic-cased cores. *Two:* Maximum built-in protection against environmental hazards. *Three:* Require no supplementary insulation prior to winding and can be vacuum impregnated after winding.

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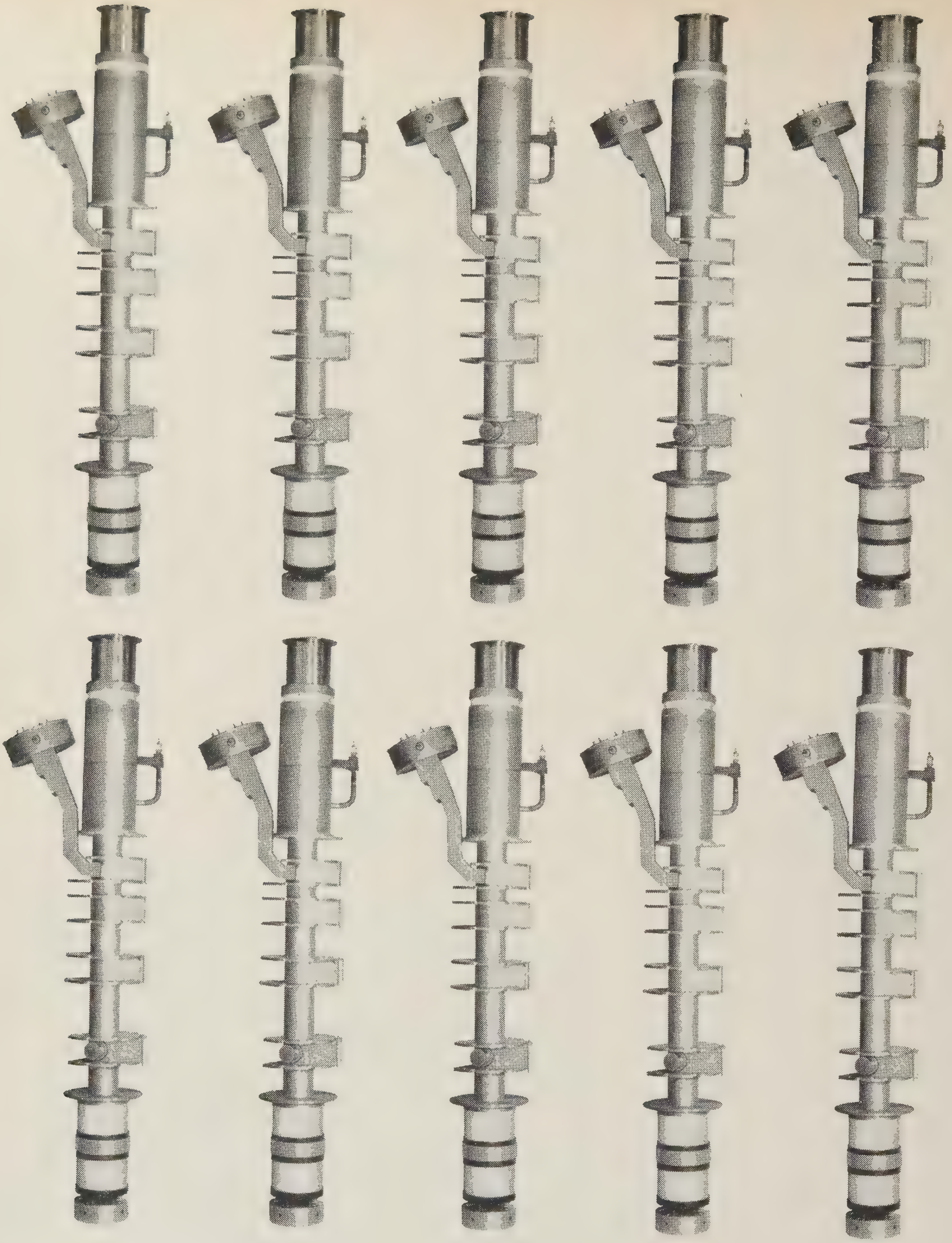
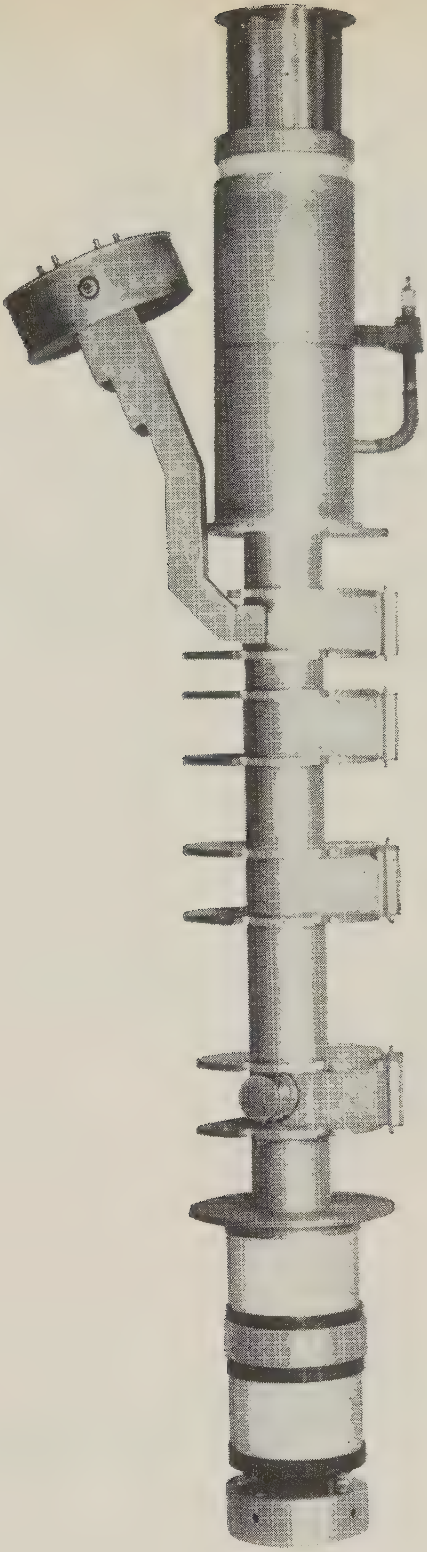


Today it would take ten super-klystrons to generate more than a megawatt of average power. But now Eimac is ready to do it



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Warm-up: Instantaneous.
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Recording Media: Rectilinear Heat or Electric, Curvilinear ink or electric, easily converted.
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(Suburb of Chicago)

WESCON
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(Continued from page 90A)

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Deltime, Inc.	714
DeMornay-Bonardi	1414-1416
Dempa Shinbun, Inc.	4102-4106
Denki Kogyo Shinbun	4114
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Deutsch Company	2619
Develop-Amatic Engineering	4725
Device Seals, Inc.	3715
Di/An Controls, Inc.	4316
Dialight Corporation	2519-2521
Dick Company, A. B.	117
Dielectric Products Engineering Co., Inc.	4411
Digital Equipment Corporation	1211
Dit-Mco, Inc.	2625-2626
DoAll Company	5012
Douglas Microwave Co., Inc.	202
Dow Corning Corporation	5102-5106
Drake Manufacturing Company	318
Dressen-Barnes Corporation	2101-2102
Driver-Harris Company	4421
Driver Company, Wilbur B.	4714
Du Mont Laboratories, Allen B.	1614-1620
Duncan Electronics, Inc.	808
DuPont de Nemours & Co., Inc., E. I.	4030-4032, 4330-4332
Dynacor, Inc.	3122
Dynamic Gear Co., Inc.	1322
E-H Research Laboratories, Inc.	3613-3615
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ESC Electronics Corp.	2609
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Edison Industries, Thomas A.	718-720
Eitel-McCullough, Inc.	1720-1724
Elco Corporation	2124-2125
Eldorado Electronics	4217
Electra Manufacturing Co.	2317-2319
Electralab Printed Electronics Corp.	109
Electric Autolite Company	2620-2621
Electric Hotpack Company, Inc.	5023
Electrical Industries, Div. of Phillips Electronics & Pharmaceutical Industries Corp.	3005
Electro Devices, Inc.	5110
Electro Engineering Works	2301
Electro Instruments, Inc.	2103-2104
Electro-Mechanical Specialties Co., Inc.	1422
Electro-Optical Instruments, Inc.	3714
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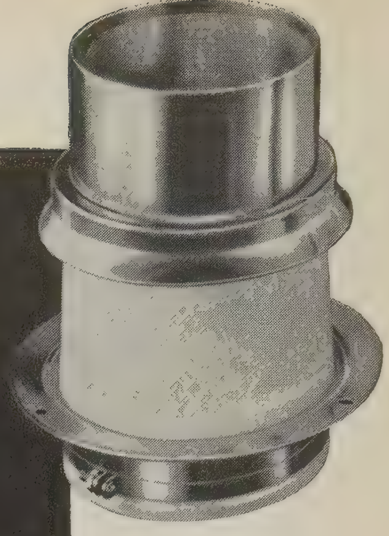
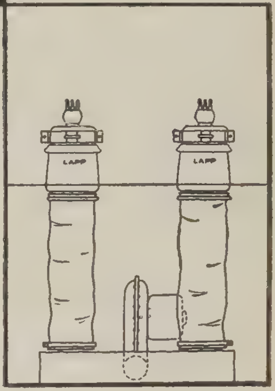
Electro Switch Corporation	4401
Electron Products Div., Marshall Industries	1016
Electronic Associates, Inc.	2303-2305
Electronic Enclosures, Inc.	4632-4634
Electronic Engineering Co. of Calif.	2320-2326
Electronic Equipment Engineering (Sutton Publishing Co., Inc.)	P-18
Electronic Instrument Co.	413
Electronic Measurements Co., Inc.	1324-1325
Electronic News	P-5

(Continued on page 96A)

Lapp
TUBE SUPPORTS
for air-cooled
power tubes





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(Continued from page 95A)

Electronic Research Associates, Inc.	3217-3219
Electronic/Sources	P-3
Electropot, Inc.	1203
Elgin National Watch Co., Electronics Div.	1802-1804
Emerson & Cuming, Inc.	810-812
Engelhard Industries, Inc.	2530-2532
Epsco, Inc.	1413-1415
Equipto Electronics Corporation	4527
Erie Pacific Div., Erie Resistor Corp.	1710-1712
Eubanks Engineering Co.	4620
Evra, Inc.	4723
Exact Engineering & Manufacturing, Inc.	115
FXR, Inc., Div. of Amphenol-Borg Electronics Corp.	220-222
Fairchild Camera & Instrument Corp., Defense Products Div.	818
Fairchild Controls Corp.	820-822
Fairchild Semiconductor Corp.	814-816
Fanon Transistor Corp.	4409
Fansteel Metallurgical Corp.	606-610
Faradyne Electronics Corp.	4103
Fenwal Electronics, Inc.	3512
Ferranti Electric, Inc.	3013-3015
Ferro Magnetics Company	1117
Ferroxcube Corp. of America	107
Fidelitone Microwave, Inc.	2515
Field Emission Corporation	118
Filmohm Corp.	1006
Filtors, Inc.	513-515
Filtron Company, Inc.	1622
Flight Electronics Corp.	1222
Flite Electronic Wire & Components, Inc.	5028
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G-L Electronics Company, Inc.	322
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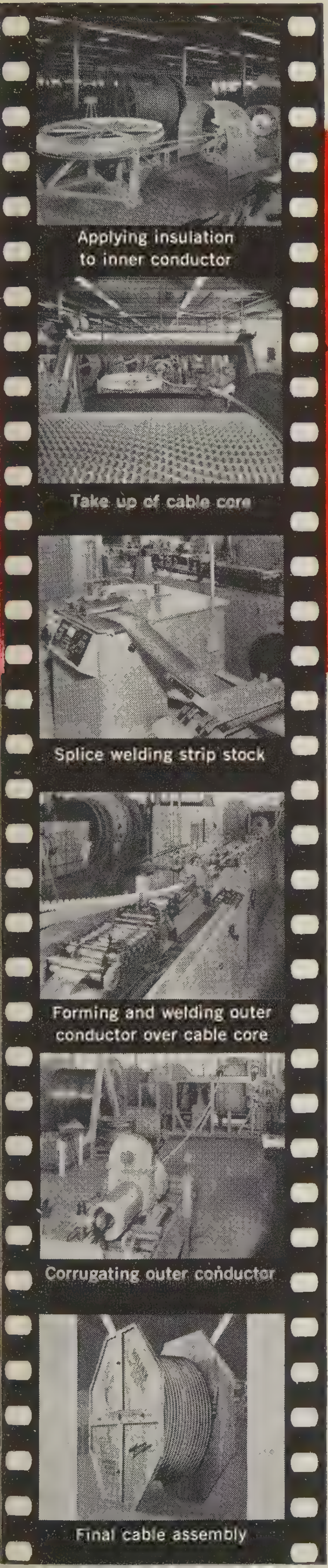
GPS Instrument Co., Inc.	4417
Gamewell Company	4407
Gamma Research Laboratory Corp.	4719
Garlock Electronic Products	4118
Garlynn Engineering	4534
Garrett Corporation	4402-4404
Gates Radio Company	514
Geist Company, W. K.	3305-3307
General Communication Co.	4302
General Controls Company	1114
General Dynamics/Astronautics	2607-2608
General Dynamics/Electronics (Convair)	201-203, 208
General Electric Company	701-710
General Electric Company, Electronic Components Div.	2214-2216
General Electric Company, Laminated Products Div.	4811
General Findings, Inc.	4809

(Continued on page 98A)

ANDREW

Production scenes



Applying insulation to inner conductor

Take up of cable core

Splice welding strip stock

Forming and welding outer conductor over cable core

Corrugating outer conductor

Final cable assembly

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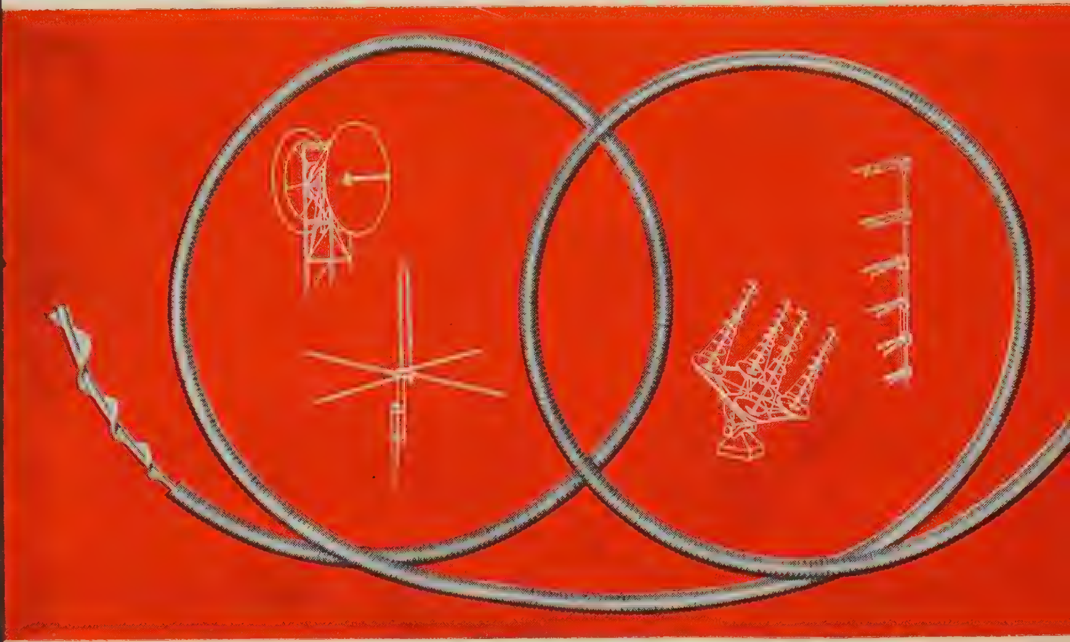

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STANDARD SIZES AND TYPE NUMBERS

SIZE	IMPEDANCE	TYPE NO.
3/8	50	H3-50
7/8	50	H5-50
7/8	75	H5-75
7/8	100	HT5-100
1 5/8	50	H7-50
1 5/8	75	H7-75
1 5/8	100	H7-100
3 1/8	50	H2-50
3 1/8	75	H2-75

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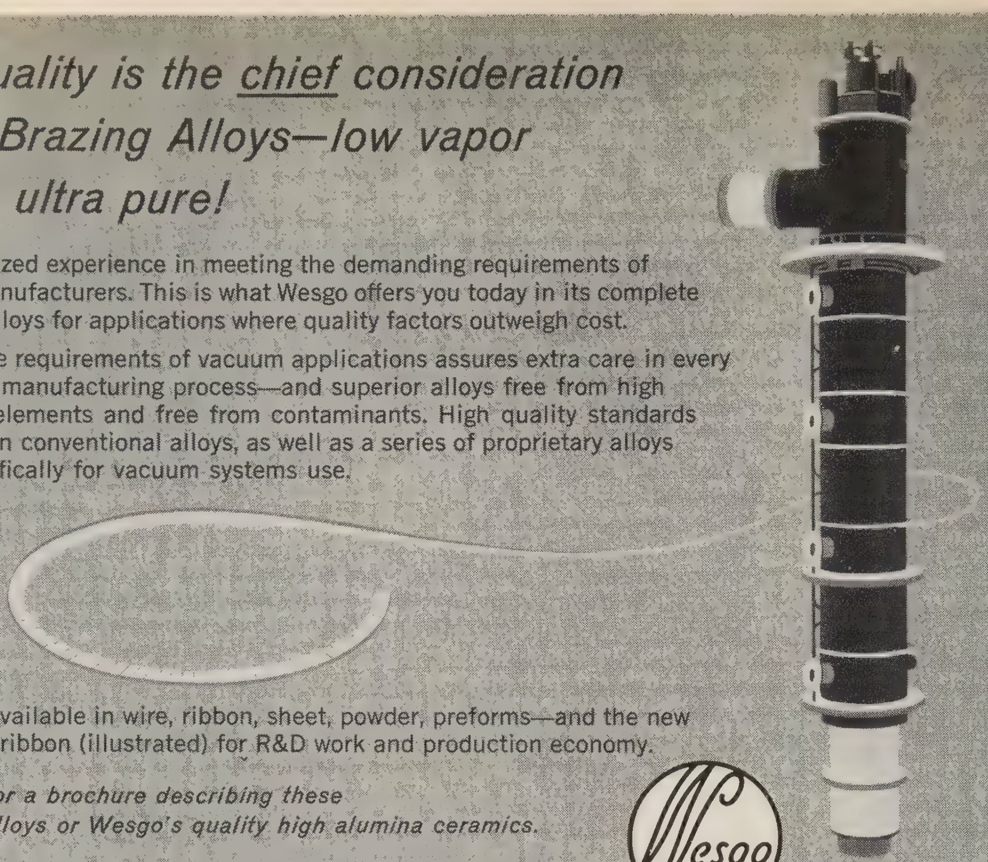
Boston • New York • Washington • Los Angeles • Toronto

Where quality is the chief consideration WESGO Brazing Alloys—low vapor pressure, ultra pure!

Years of specialized experience in meeting the demanding requirements of vacuum tube manufacturers. This is what Wesgo offers you today in its complete line of brazing alloys for applications where quality factors outweigh cost.

Knowledge of the requirements of vacuum applications assures extra care in every step of Wesgo's manufacturing process—and superior alloys free from high vapor pressure elements and free from contaminants. High quality standards are maintained in conventional alloys, as well as a series of proprietary alloys developed specifically for vacuum systems use.



Wesgo alloys are available in wire, ribbon, sheet, powder, preforms—and the new Flexibraze slotted ribbon (illustrated) for R&D work and production economy.

Write today for a brochure describing these alloys or Wesgo's quality high alumina ceramics.

WESTERN GOLD & PLATINUM COMPANY
Dept. P8, 525 Harbor Blvd. • Belmont, California • LYtell 3-3121

Be sure to Visit
COMINCO PRODUCTS, INC.
Booth 4530
WESCON Show
San Francisco
Aug. 22-25
Indium Antimonide
Aluminum-Boron
Fabrications
High Purity Metals
Dot Materials

COMINCO PRODUCTS, INC.
Electronic Materials Dept.
Spokane, Washington

WESCON
EXHIBITORS' LIST

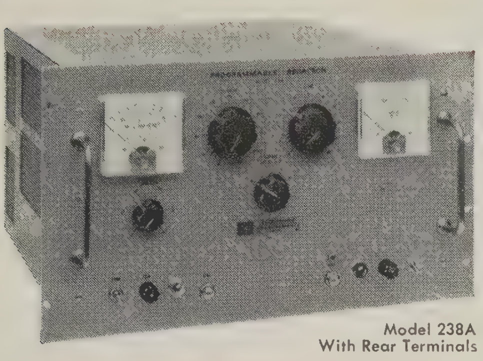
(Continued from page 96A)

General Instrument Corp., Capacitor Div.	1912
General Plastics Corp.	5025
General Precision, Inc.	3309-3321
General Radio Company	2202-2204
General Time Corporation	613
Genisco, Inc.	3702-3704
Gertsch Products, Inc.	1602-1606
Giannini Controls Corp.	1417-1419
Globe Industries, Inc.	1812
Goodrich Company, B. F.	1215
Goodrich Co., B. F., Rivnut Div.	5026
Gorman Machine Corporation	5119
Gould-National Batteries, Inc., Nicad Div.	102-104
Granger Associates	3012
Grant Pulley & Hardware Corp.	4711
Grayhill, Inc.	422
Gremar Manufacturing Co., Inc.	1512
Guardian Electric Mfg. Co.	4408-4410
Gudebrod Bros. Silk Co., Inc.	4718
Gurley, W. & L. E.	2604
Halliburton Enterprises, Inc.	4912-4914
Harman-Kardon, Inc.	4129
Harowe Servo Controls, Inc.	4510
Harrison Laboratories, Inc.	1008-1010
Hartwell Corporation	4826
Hastings-Raydist, Inc.	2821
Hathaway Denver, Div. of Hathaway Instruments, Inc.	1608-1610
Hayden Publishing Co., Inc.	P-1, P-2
Haydon Company, A. W.	2802-2804
Heinemann Electric Company	3701-3703
Hermetic Pacific Corporation	1707-1709
Herrmann Associates, Carl	611
Hevi-Duty Electric Company	5027
Hewlett-Packard Company	2313-2318
Hexacon Electric Company	5033
Hi-G, Inc.	3009-3011
Hickok Electrical Instrument Co.	3220-3222
Hill Company, J. T.	1612
Hill Magnetic Products	218
Hirschmann Company, Inc., Carl	5108
Hitemp Wires, Div. of Simplex Wire and Cable Co.	4805
Hoffman Electronics Corp.	1615-1623
Holbrook Merrill Company	5032
Hoover Company	1106
Hopkins Engineering Co.	3109
Houston Instrument Corp.	407
Hudson Tool & Die Company, Inc.	5034
Huggins Laboratories, Inc.	2308-2310
Hughes Aircraft Company	2421-2427
Hughes Aircraft Co., Vacuum Tube Products Div.	3106-3108
Hunter Sales Co., Inc., R. N.	4730
Hy-Gain Antenna Company	415
Hysol of California	4821
ISI-Computer Products	1208
Iconix, Inc.	4521
Ideal Precision Meter Co., Inc.	213
Illumitronic Engineering Corp.	116
Indiana General Corp.	2107-2108
Industrial Electronic Engineers, Inc.	3718

(Continued on page 100A)

FROM ELECTRONIC MEASUREMENTS

0–1500 V DC POWER SUPPLIES



Model 238A
With Rear Terminals

CONSTANT-VOLTAGE

In addition to covering a complete voltage range—0 to 1500 V—this programmable, regulated power supply can deliver rated current of 100 ma at any output voltage . . . even at less than a volt.

But an even more useful feature is its continuously variable current-limiting control. Here's a feature that's finding more application with every passing day.

When it comes to regulation, the Model 238A is truly flexible. Standard regulation is 0.1% line or load. However, 0.01% regulation is available by means of an optional plug-in chopper unit.

The chart below lists just a few of the many Electronic Measurements off-the-shelf, constant-voltage power supplies. For complete information request Catalog BR1961.

	RANGE	
MODEL	VOLTS DC	CURRENT
238A	0-1500 V DC	0-100 MA
239A	0-600 V DC	0-1 AMP
235A	0-600 V DC	0-500 MA
234A	0-300 V DC	0-500 MA
230A	0-200 V DC	0-1 AMP
228A	0-150 V DC	0-1 AMP
229A	0-150 V DC	0-300 MA
218A	0-100 V DC	0-3 AMP
221A	0-100 V DC	0-500 MA
225A	0-75 V DC	0-2 AMP
215A	0-50 V DC	0-3 AMP

Model C638A
With Rear Terminals

CONSTANT-CURRENT

Here's the newest in Electronic Measurements' line of Constant Current Power Supplies . . . a full 1500 V compliance at constant current outputs from less than a ma to 100 ma. Like all Electronic Measurements Power Supplies, the Model C638A has a lot of built-in extras too. For example, there's a modulation input . . . there are also provisions for remote programming . . . and an adjustable voltage compliance control that in effect provides for voltage-limiting.

Specifications include a high output impedance of 10^4 megohms at 0.5 μa to 0.5 megohm at 100 ma. Above 2.2 μa, regulation is better than 0.15%, line or load. Ripple is less than 0.01% +1 μa.

The following listing shows some of the constant current models available. For complete information, request Specification Sheet 3072B.

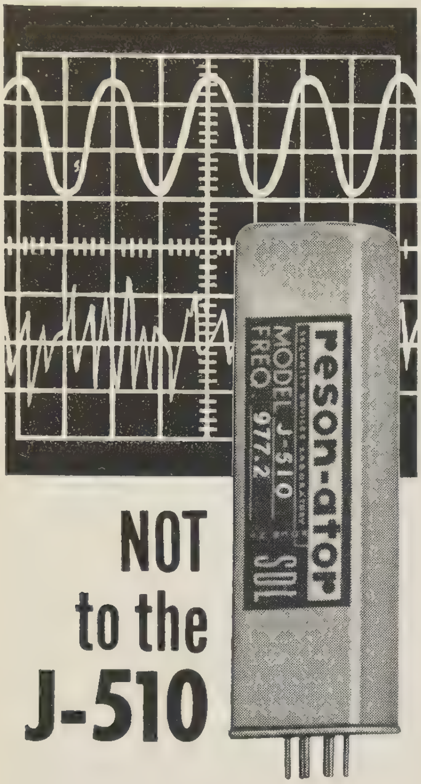
	RANGE		VOLTAGE COMPLIANCE
MODEL	MIN.	MAX.	(MINIMUM)
C614A	10 μa	1 AMP	100 V
C613A	10 μa	1 AMP	50 V
C621A	5 μa	500 MA	100 V
C620A	5 μa	500 MA	50 V
C633A	2.2 μa	300 MA	300 V
C629A	2.2 μa	300 MA	50 V
C632A	2.2 μa	220 MA	300 V
C624A	2.2 μa	220 MA	100 V
C638A	1 μa	100 MA	1500 V
C631A	1 μa	100 MA	300 V
C612A	1 μa	100 MA	100 V

SEE THEM AT WESCON • BOOTHS 1324 AND 1325

E/M

ELECTRONIC
MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN • NEW JERSEY

GOBBLE-DE-GOOK?



NOT to the J-510

Upper trace in oscilloscope pattern above shows output wave of an audio oscillator. Outputs of twenty individual oscillators (frequencies ranging from 88 to 716 cps) were mixed, resulting in complex waveform shown in lower trace of oscilloscope. Twenty J-510 Resonator Resonant Reed Relay controls with resonant frequencies corresponding to those oscillators were connected in parallel and exposed to the complex waveform. All J-510s closed within milliseconds.

When the signal corresponding to mechanical resonant frequency of any J-510 Resonator was removed from complex wave, the corresponding Resonator ceased to function. When tone was replaced, the Resonator triggered immediately. In this way strict control of each individual Resonator was accomplished, **proving** that the J-510 even when exposed to a complex waveform is capable of sensing the presence of a component corresponding to its mechanical resonant frequency.

These filtering capabilities of the J-510 now make possible a multitude of applications in the fields of selective signaling, data transmission, remote control and telemetering.

SDL
SECURITY DEVICES LABORATORY
ROCHESTER 21, NEW YORK

WESCON
EXHIBITORS' LIST

(Continued from page 98A)

Industrial Test Equipment Co.	2415
Ingersoll Products, Div. of Borg-Warner Corp.	4916-4918
Inland Motor Corp. of Virginia	1306
Inso Electronic Products, Inc.	4529
Institute of Radio Engineers	P-12
Instrument Development Laboratories, Inc.	1310
Instruments Publishing Co., Inc.	P-19
International Communications Corp.	1220
International Eastern Company	5115
International Electronic Industries, Inc.	4201-4203
International Electronic Research Corp.	1504-1505
International Rectifier Corp.	1701-1703
International Resistance Company	2307-2311
International Telephone & Telegraph Corp.	801-806
Interstate Electronics Corp.	2817
Iron Fireman Mfg. Co., Electronics Div.	1316-1317
Isotronics, Inc.	1713
J-B-T Instruments, Inc.	2527
JFD Electronics Corporation	621
J-Omega Company	4514
Japan Electric Industry	4108-4112
Jennings Radio Mfg. Corp.	1901-1902
Jerrold Electronics Corp.	1002-1004
Jewett Company	2920
Jonathan Electronics Corp.	1013, 4830
Joy Manufacturing Company	4229
Kay Electric Company	3105-3107
Kaynar Mfg. Co., Inc.	5124
Keithley Instruments, Inc.	3019-3021
Kempf Company, J. S.	4505
Kepco, Inc.	501-503
Kester Solder Company	5017-5019
Kewaunee Scientific Equipment	5129
Key Resistor Corporation	3210
Kin Tel, Div. of Cohu Electronics, Inc.	2019-2021
Kinetics Corporation	4230
King Engineering Co.	910
Kingsley Machine Company	4820
Kinney Vacuum Div., New York Air Brake Co.	4926
Kittleson Company	1801-1803
Klein & Sons, Inc., Mathias	5116
Knight Electronics Corp.	906-908
Knights Company, James	1509
Krohn-Hite Corporation	219
Kurman Electric Company	320
LEL, Inc.	4322
Laboratory for Electronics	2408-2410
Lambda Electronics Corp.	3602-3604
Land-Air, Inc.	3612
Leach Corporation	1605-1609
Lenkurt Electric Co., Inc.	1521
Licon Div., Illinois Tool Works	619
Lindberg Engineering Co.	4427
Ling-Temco Electronics, Inc.	4121-4127, 4022-4028
Littelfuse, Inc.	302
Litton Industries	601-607, 502-508

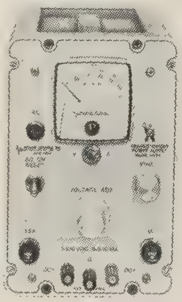
(Continued on page 112A)

WIDE RANGE

MODEL
105TA
WITH

ROBOTEC
overload and short protection
and
HEATRAN
electronic dissipation control

$239.50
FOB FACTORY
WESCON BOOTH 2705



SEMICONDUCTORIZED POWER SUPPLY 1-100 VDC 0-0.5 AMP

High efficiency, stabilized solid state DC power supply with .05% regulation, 1 millivolt ripple, .025 ohm source impedance, 50 microsecond response time, 55-440 cycle input.

IMMEDIATE DELIVERY

Power Designs inc.
1700 SHAMES DRIVE, WESTBURY, NEW YORK
EDgewood 3-6200 (LD Area Code 516)

Readouts that do more...

Series 80ooo

DISPLAY NUMBERS, WORDS, COLOR, and SYMBOLS

Features the largest readout area (7⅞ sq. in.) employing these applications. Price complete from $33.00. Your inquiry regarding readouts that do more, for you, is invited.

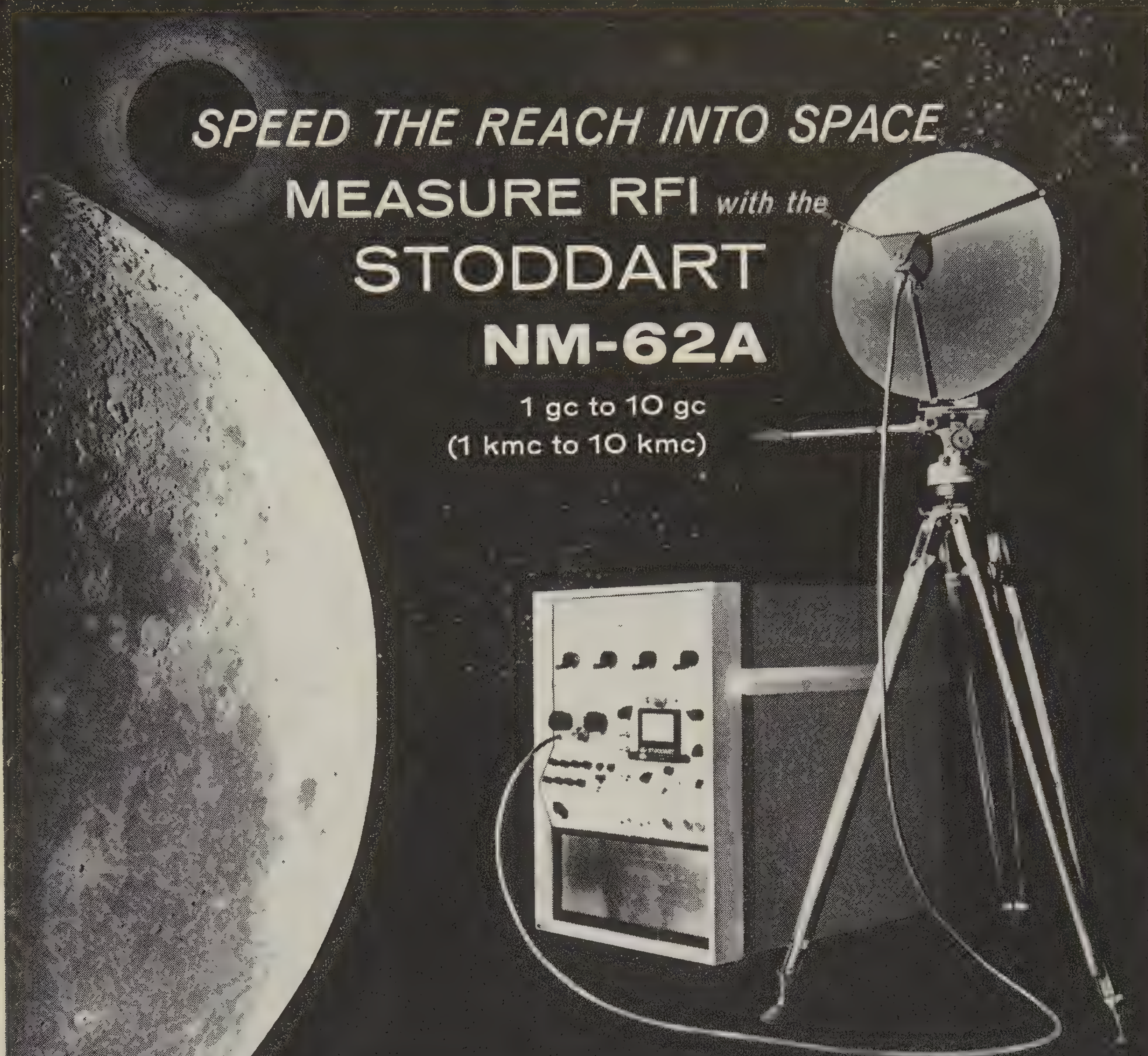
INDUSTRIAL ELECTRONIC ENGINEERS, Inc.
5528 Vineland Ave., North Hollywood, Calif.

SPEED THE REACH INTO SPACE

MEASURE RFI *with the* STODDART

NM-62A

1 gc to 10 gc
(1 kmc to 10 kmc)



Man's steps into far space are daily becoming longer and faster . . . and the reach toward new worlds brings a constant thickening of interference problems. **STODDART—leader in the field of radio interference control**—now adds new dimensions to RFI measurement techniques with the NM-62A Interference Measuring Instrumentation.

The NM-62A is designed and manufactured to rigid military equipment specifications for use by all government services, as well as industry. This **completely self-contained, compact unit cuts operating time and cost**, and advances the state of the art by providing:

- **AUTOMATIC FREQUENCY SCANNING** over entire range of 1 to 10 gc
- **AUTOMATIC TUNER SELECTION**
- **AUTOMATIC RECORDING** of amplitude vs. frequency
- **MOTORIZED TUNER SCANNING**

See this new and revolutionary instrument at the **Wescon Show Booth 205**. We invite your immediate request for complete details and specifications.

STODDART
AIRCRAFT RADIO CO., INC.
6644 SANTA MONICA BLVD.
HOLLYWOOD 38, CALIFORNIA
HOllywood 4-9292
serving 33 countries in Radio Interference control

Major Systems Programs Pinpoint Opportunities In 26 Areas Of Specialization

Traditional boundaries of defense system definitions are giving way to new, vast-scale operational requirements that may extend from the ocean depths to deep space. ▪ Right now, a number of new programs at Defense Systems Department call for backgrounds ranging from Oceanography to Space Physics. ▪ Openings for graduate engineers at all levels of competence are immediately available on project groups undergoing expansion and new groups currently being organized.

Specific experience is sought in these fields:

Applied Mathematics / Astronomy / Auto Pilots / Classical Mathematics / Communications / Computers / Computer Application Engineering / Data Handling / Guidance Equations Inertial Guidance / Infra-Red / Nuclear Physics / Oceanography Operations Analysis / Optics / Propagation Engineering / Radar Radiation Physics / Sonar / Space Physics / Systems Analysis Systems Engineering / Systems Synthesis / Systems Test Engineering / Technical Writing / Weapons Systems Analysis

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Write in confidence, briefly outlining your education and professional experience to
Mr. P. W. Christos, Dept. 53-MH.

DSD DEFENSE SYSTEMS DEPARTMENT
A Department of the Defense Electronics Division

GENERAL ELECTRIC

Northern Lights Office Building—Syracuse, New York

Positions Open

The following positions of interest to IRE members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. ....

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

Proceedings of the IRE
1 East 79th St., New York 21, N.Y.

INSTRUCTOR—PROFESSOR

Electrical Engineering staff openings in an expanding undergraduate program. (1) Instructor: to teach undergraduate courses to sophomore and junior engineering students. Candidate must have B.S. degree and be willing to take graduate work at nearby University. (2) Assistant, associate or full Professor: to teach electronics and senior E.E. electives. Candidate should possess a graduate degree (M.S. or Ph.D.) specializing in electronics and/or communications. Encouragement given to private research and consultation. Rank and salary commensurate with academic attainment and experience. Apply: L. M. Gonsalves, Chairman, Dept. of E.E., New Bedford Institute of Technology, New Bedford, Mass.

ELECTRONICS INSTRUCTOR

Junior College: to teach general electronics theory and math., pulse circuits, measurements, transistors. State experience in the fields of TV, radar, computers, magnetic amplifiers, microwaves. Send resume and references to College Supervisor, Certified Selection. Personnel Div., Los Angeles City Board of Education, 450 North Grand Ave., Los Angeles 12, Calif.

PART TIME EMPLOYMENT

Part time job for semi-retired salesman experienced in electrical-electronic-mechanical field. Newly established company. Commission basis. Write Box 2051.

ENGINEER—MATHEMATICIAN

We should like to add a Statistical Mathematician to our staff, who would be concerned with problems in the information processing area—more specifically, projects utilizing statistical decision theory, perception recognition and factor analysis. An example of some current research in this area is Pattern Recognition Studies: decision criteria, tests, statistical analysis, and rating factors applicable to pattern recognition problems are being investigated. Mathematical models including the use of the analysis of stochastic processes will be used to develop criteria and system parameters within the various areas of recognition research, information retrieval and artificial intelligence. Send inquiries to Dr. Donald Brick, Mgr., Information Processing Dept., Sylvania Electronic Systems, 100 First Ave., Waltham 54, Mass.

DELAY LINES

Electrical Engineer with design experience involving components for pulse circuitry with emphasis on lumped and distributed delay lines. Background in filters, R.F. coils, and pulse transformers also desirable. This position with progressive and expanding eastern components manufacturer, offers excellent opportunity for eventual advancement to position of Chief Engineer. Send complete resume and salary requirements with first letter to Box 2052.

(Continued on page 104A)

YOU'RE STILL TUNED IN, HERR PROFESSOR DOPPLER!

Back in 1930, your principle helped provide the first step in the development of radar. Since that time, radar has grown up . . . always depending on the Doppler shift to measure the velocity of a moving object. Now, we're about to put your principle to work again; this time as an integral part of the Bombing Navigation System for the B-52 weapons system.

If you would like to help us apply yesterday's principles, like Doppler's, to important projects like B-52 navigation, and if you have a BS, MS or PhD in EE, ME, Physics or Math, please contact Mr. G. F. Raasch, Director of Scientific and Professional Employment, Dept. B, 7929 S. Howell, Milwaukee 1, Wisconsin.

All qualified applicants will be considered without regard to race, creed, color or national origin.

AC SPARK PLUG ⚛ THE ELECTRONICS DIVISION OF GENERAL MOTORS
MILWAUKEE • LOS ANGELES • BOSTON

ACF ELECTRONICS

. . . where your status as an
individual and your career
in engineering grow
hand in hand —
day by day!

You can bring new meaning to your career in engineering by investigating opportunities in state-of-the-art developments at ACF. Experienced engineers at all levels are cordially invited to inquire about challenging positions in the following fields:

ANALOG & DIGITAL TECHNIQUES
SIMULATOR ENGINEERING
IONOSPHERIC PROPAGATION
HF, RF COMMUNICATIONS
MICROWAVE COMPONENTS & SYSTEMS
OPTICS & INFRARED
AIRBORNE RADAR SYSTEMS
FIELD ENGINEERING

These openings involve assignments at our laboratories located in SUBURBAN WASHINGTON, D. C. and the New York metropolitan area at Paramus, New Jersey. Pleasant residential neighborhoods provide readily available housing. Advanced study under tuition refund may be conducted at nearby universities. All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Send resume to:
A. C. SUGALSKI
Manager,
Professional Employment
at our Riverdale Facility
Dept. 2

ACF ELECTRONICS
DIVISION

ACF INDUSTRIES

RIVERDALE, MARYLAND • HYATTSVILLE, MARYLAND • PARAMUS, NEW JERSEY

Positions Open

(Continued from page 102A)

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING

Ph.D. required with special interests in circuits, controls or electromagnetic theory to teach and do research. Foreign applications welcome. Apply to Chairman of E.E. Dept., Villanova University, Villanova, Pa.

ELECTRONIC RESEARCH ENGINEERS

4-20 years experience, M.E.E. or D.E.E. Research positions are open for Senior Electronic Engineers interested in sophisticated programs on multi-dimensional radar resolution, secure communications, space guidance, AICBM radar, superresolution pulse compression and long range sonar. The work includes theoretical and laboratory research relating to communication and radar systems analysis, network synthesis, digital techniques, statistical communication theory, computer design, error analysis and operations research. Contact Donald Richman, Assoc. Director of Research, Hazeltine Research Corp., Little Neck 62, N.Y. FAculty 1-2300 (NYC). Positions are at the Plainview, Long Island, laboratory.

ELECTRONIC ENGINEERS & ELECTROMECHANICAL ENGINEERS

Electronic Engineers with experience in digital system design, digital analysis and design, plus circuitry, simulation, and telemetry. To work on computers, test equipment and instrumentation. Electromechanical Engineers with experience in servos, switches, relays and analog computers. To work on trainers and simulators. Address resume to D. J. Wishart, Aircraft Armaments, Inc., Cockeysville, Maryland.

CHIEF ENGINEER—MILITARY ELECTRONICS

Unusual opportunity. $25,000 starting salary (stock options, etc.) Requires Doctorate in science, electronic engineering or physics. Must have strong engineering administrative abilities. Send complete resume to Box 2054.

ASSOCIATE OR FULL PROFESSOR

Associate or Full Professor of E.E. Ph.D. required. Interest in either electronics or power fields. Undergraduate and graduate teaching through M.S. Research activities desired, but teaching is emphasized. Salary open. Contact Prof. Edwin M. Anderson, Chairman, E.E. Dept., North Dakota State University, Fargo, North Dakota.

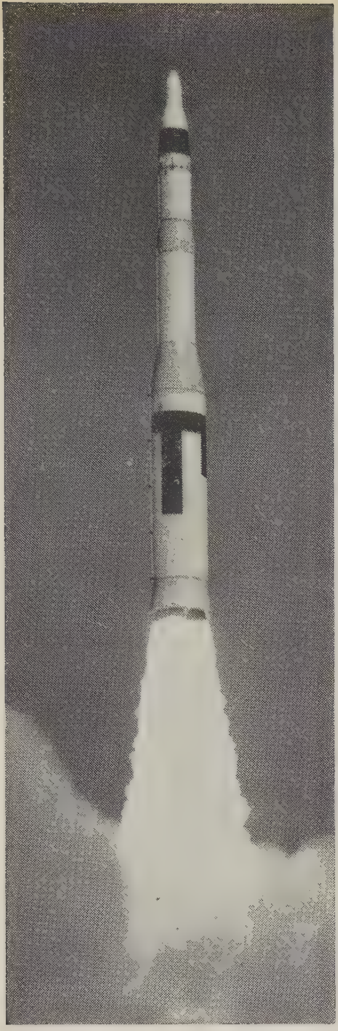
DIGITAL COMPUTER PROGRAMMER

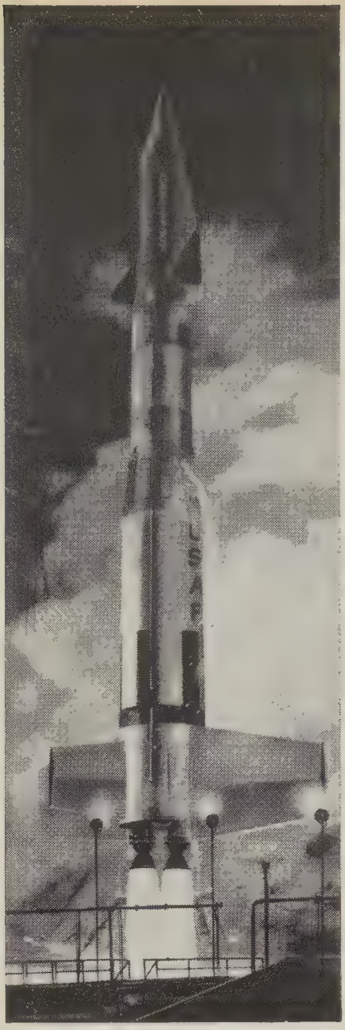
Digital Computer Programmer wanted for scientific analysis of biomedical research. Full time, permanent position. Knowledge of mathematics or statistics and programming experience required. Salary depending upon qualifications. Position includes faculty appointment in the School of Medicine. Write to Salomon Rettig, Ph.D., Research Div., Columbus Psychiatric Institute & Hospital, Ohio State University Health Center, 473 W. 12th Ave., Columbus 10, Ohio.

RESEARCH DIRECTOR

Ph.D. to head up research facilities of large capacitor manufacturer. Must have background in all dielectrics. This is top organization position. Replies in confidence. Box 2055.

(Continued on page 107A)





Immediate Minuteman and Dyna-Soar openings for Electronic and Electrical Engineers

Electronics is one of the fastest growing areas of engineering at Boeing. Electronic and electrical engineers interested in the advancement of space-age technologies will find challenging and deeply rewarding opportunities in advanced Boeing programs, including the Dyna-Soar manned space glider and the solid-fuel Minuteman ICBM. Assignments exist in your particular area of interest and at the level you require for career satisfaction and advancement. For your convenience, a professional application form appears at the right, and continues on the following page.

MAIL FORM TODAY

RETURN TO: MR. W. B. EVANS
THE BOEING COMPANY
P. O. BOX 3707-PRK
SEATTLE 24, WASHINGTON

PROFESSIONAL POSITION APPLICATION
(All replies held in strict confidence)

Date of this Application

Name
LAST FIRST MIDDLE (USE NO INITIALS)

Social Security No.

Present Address
NO. STREET
CITY ZONE STATE

Telephone No.

Ht. Wt. Age U.S. Citizen

Male Female Marital Status

No. of Children Other Dependents

U.S. Veteran Entry Date

Discharge Date

Type of Discharge

Spouse's Maiden Name

Employer

Previous Boeing Employee?

If the answer to following three questions is "yes," explain on supplementary sheet:

1) Have you any physical defects?

2) Have you ever been arrested (except traffic and juvenile)?

3) Have you ever received disability or accident compensation?

TURN PAGE ➧

HIGHER EDUCATION

College and Location	Dates Attended	Degree and Major
1.		
2.		

EMPLOYMENT HISTORY (Attach Resume)

Firm Name and Address	Base Pay 40 hr/Wk	Dates Employed Month/Year
1. Position & Duties		
2. Position & Duties		
3. Position & Duties		
4. Position & Duties		

REFERENCES. Give full names, occupations and addresses. Professional (previous supervisor preferred):

1. ____________________

2. ____________________

Character (other than relatives or former employers):

1. ____________________

2. ____________________

LIST TYPE OF WORK PREFERRED UPON EMPLOYMENT:

____

____

Have you ever been cleared for classified military information?________. If yes, give date, level and company.

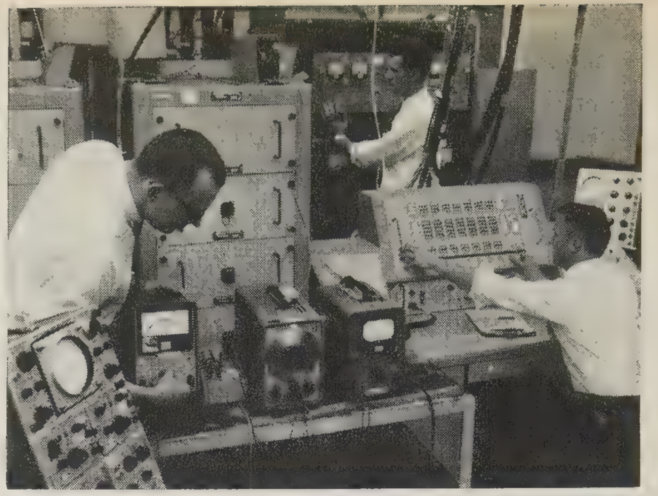
May we contact your former and present employer prior to completion of employment negotiations? Yes____ No____
If "yes," I authorize, without liability, the release of all employment and personal information.

____
SIGN YOUR NAME HERE

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

RETURN TO: MR. W. B. EVANS
THE BOEING COMPANY
P. O. BOX 3707-PRK
SEATTLE 24, WASHINGTON

Form begins on previous page



Boeing-developed command control console in Minuteman Subsystem Test Laboratory, Boeing Developmental Center.

Electronic and electrical engineers will find unique opportunities at Boeing. Activities in research, design and test are making significant contributions to the state-of-the-art as well as to the development, manufacture and installation of systems associated with Dyna-Soar, Minuteman, Bomarc, advanced aircraft, and orbital vehicle programs.

Assignments encompass broad areas of electronics activities including surveillance, communications, guidance and control, systems engineering, systems integration, antennas, cabling, circuit design, electromagnetic warfare, electronic packaging, electronics ground support, instrumentation, radio frequency interference control, reliability, systems test, solid state circuit design and many others.

Exceptional opportunities exist for logical designers and for specialists in systems design; in data processing associated with telemetry, and in digital design techniques embracing circuit and systems design, miniaturization, test and evaluation of airborne computers and supporting ground electronics.

You'll find space in the application at the left to indicate your special interests. Fill in and mail today.

* * *

Sailing on 23-mile Lake Washington in Seattle.

Matching the career advantages at Boeing are the family living advantages of the Pacific Northwest. This uncongested, evergreen area is famous for mild, year-round climate, unexcelled recreational facilities, fine modern homes, excellent educational and cultural institutions and healthful outdoor Western living for the entire family.

BOEING

Positions Open

(Continued from page 104A)

TELEVISION BROADCAST TECHNICIAN

Seeking experienced, qualified television technician for maintenance and operation at commercial VHF station in growing market. CBS affiliate; progressive management with long broadcast experience. Station is well-equipped; maximum power; 1000 foot tower; two Ampex Videotape Recorders. Applicant must be ambitious, dependable, and have 1st class phone license. Some formal schooling in electronics preferred. Salary commensurate with experience and ability. Replies treated in confidence. Write Chief Engineer, WLAC-TV, Nashville, Tenn.

ASSISTANT CHIEF ENGINEER

Seeking college graduate electronics engineer to assist Chief Engineer of commercial VHF television station in growing market. CBS affiliate; progressive management with long broadcast experience; good record of low personnel turnover. Majority of equipment RCA; two Ampex Videotape Recorders; maximum power; 1000 foot tower. Applicant should be capable of doing design and construction work, and should have some administrative ability. Salary commensurate with experience and ability. Replies treated in confidence. Write Chief Engineer, WLAC-TV, Nashville, Tenn.

COMMUNICATION ENGINEER

College graduate interested in associating with long established public service company serving Middle America. Position open at Engineering Dept., Tropical Radio Telegraph Co., P.O. Drawer 97, Hingham, Mass. (near Boston).

SENIOR ELECTRONIC ENGINEER

Opening for an electronic engineer with experience in circuitry, instrumentation and product design with a B.S. in E.E. and at least 5 years of experience. High salary. Excellent opportunity for advancement to the position of Chief Engineer. Opportunity for higher degree with tuition paid. Send complete resume to Ad-Yu Electronics Lab., Inc., 249 Terhune Ave., Passaic, New Jersey.

DEPARTMENT HEAD

Head professor for 12-man E.E. Department. Excellent opportunity for energetic and progressive Ph.D. with experience and potential to build, administer, and participate in a balanced program of teaching, research, and extension. Box 2056.

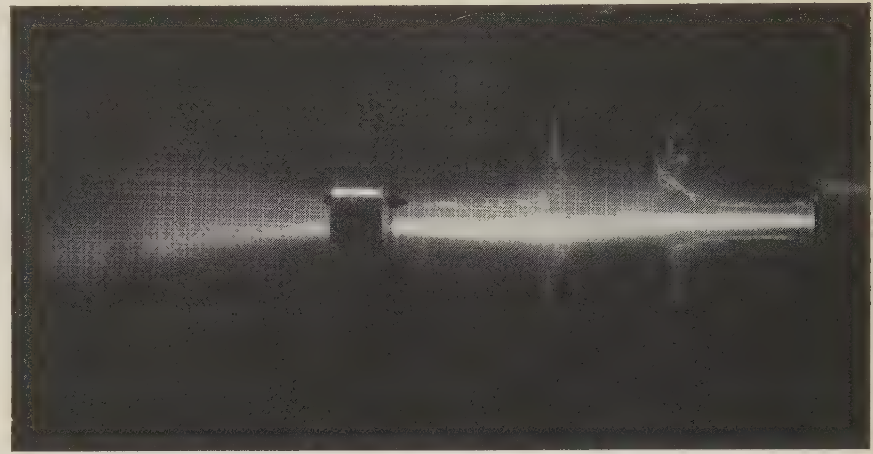
ANTARCTIC RESEARCHER

Douglas Aircraft has an opening at Antarctic station for experimental investigations of the ionospheric absorption of extraterrestrial radio waves. Applicants must have an advanced degree (or equivalent) in physics or electrical engineering with a knowledge of ionospheric physics and/or solar flare events and r. f. propagation in the atmosphere. Experience required in data reduction and analysis, scientific instrumentation, and communication systems. Applicants should also be familiar with operation of a riometer, although not required. In order to qualify, individual must be 21 years of age, single (preferred), and will be required to pass stringent medical examination. Apply to S. Amestoy, Douglas Aircraft Co., Inc., 3000 Ocean Park Blvd., Santa Monica, Calif.

(Continued on page 108A)

ELECTRICAL ENGINEERS

for advanced studies of high-performance electrical propulsion systems...



Great interest has been aroused by our unusual oscillating-electron ion engine which produces a high-velocity, electrically-neutral plasma beam. Since this electrically-neutral stream eliminates the space-charge effect, there is no theoretical limit to the thrust capability of the device. ● Past successes and current progress with this device, (and in other areas of plasma research) now require a material expansion in this entire effort. As a result, a number of very attractive Senior Positions are being created for electrical propulsion specialists — particularly physicists with advanced degrees and experience. ● These positions should have particular appeal to those interested in studies of high-energy plasma sources, diagnostic techniques and other basic investigations that will lead to practical space propulsion devices. Included are both theoretical and experimental investigations of factors that determine plasma potentials, ionization and power efficiencies. ● This program is of the long-range sustained type with both corporate and government sponsorship. Superior facilities and assistance are available for numerical computation and experimental work. Publication of papers is encouraged as is close contact with related university research. ● Salary levels, benefits and the semi-academic approach will appeal to experienced men with demonstrated abilities.

You are invited to contact Mr. W. B. Walsh, Personnel Department

RESEARCH LABORATORIES
UNITED AIRCRAFT CORPORATION
400 Main Street, East Hartford 8, Conn.

ENGINEERS
PHYSICISTS
MATHEMATICIANS

SYSTEMS
EVALUATION
POLARIS SYSTEM

The Applied Physics Laboratory of The Johns Hopkins University has responsibilities in the evaluation of the Polaris Missile System. We invite you to consider the following career appointments:

Senior Mathematicians

Duties will involve statistical analysis of complex test data for performance, reliability and operation evaluations. A background in physics or electrical engineering is desirable.

Project Engineers

For field test operations involving a team effort of Contractor, Navy and APL Personnel. Work will include launch and flight data acquisition analysis and monitoring of shipboard activities related to the Polaris Missile System. Prefer engineers with considerable background of project level responsibilities.

Systems Engineers

APL has several positions available on the associate and senior levels for men with experience in electrical engineering, physics, mechanical engineering, dynamics, or computer engineering. Will perform systems work related to fire control, navigation, missiles, and submarine controls. Assignment involves field work and contact with the Navy and Contractor Personnel.

Systems Analysts

Respondents must have heavy theoretical background and ability to read and understand telemetry records. Will perform basic analysis of systems related to fire control, navigation, missiles, and submarine controls. May also be required to simulate and solve orbit and doppler equations. Associate and senior level appointments.

Data Requirements, Instrument Engineers

Positions require a physicist or electrical engineer with experience in evaluation, data acquisition and testing of instrumentation installations. Will analyze sub-systems such as guidance, propulsion, controls, boosters, and inertial systems individually and as integral parts of over-all systems to derive data requirements and instrumentation. Duties involve some field work.

APL will provide you with a professional atmosphere conducive to creative effort as well as the tools and technical support required to tackle these and related problems. Our facilities are located in Silver Spring, a residential suburb of Washington, D. C., offering you a choice of country, suburban or city living.

For additional details,
direct your inquiry to:
Professional Staff Appointments

The Applied Physics Laboratory
The Johns Hopkins University
8603 Georgia Avenue, Silver Spring, Md.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Positions Open

(Continued from page 107A)

OVERSEAS FIELD ENGINEER

Electronic Field Engineers are needed for overseas assignments. Applicants must have a B.S. degree and at least 1 year of experience in electronics and must possess initiative, ingenuity, and the ability to get a job done. Base salary during training in Denver with overseas differential and per diem while on overseas assignment. Address inquiries to: C. A. Hedberg, Head, Electronics Div., Denver Research Institute, University of Denver, Denver 10, Colo.

ANTENNA ENGINEER

Experienced in antenna design and project work in the field of communications antenna systems. Write including complete resume and salary requirements to Roger Olson, Director of Engineering, Hy-Gain Antenna Products Corp., 1135 North 22nd St., Lincoln, Nebraska.

COMPUTER DEVELOPMENT ENGINEER

An attractive position open for a qualified engineer or scientist interested in exploiting and developing ideas in areas of pattern recognition and artificial intelligence as well as more conventional computers. Scope of work extends from first conception to working models. Experience (4-8 years) in design of special data processing equipment, self-organizing systems, or input-output equipment is desirable. A broad and expanding program based on notions developed out of our work with the Perceptron requires a high level scientist or engineer who will creatively apply ideas to significant applications broadly ranging from photo-interpretation to alphabet-to-binary transliteration. A stimulating R&D atmosphere prevails, and the opportunity exists for professional development. Contact B. C. Rentschler, Cornell Aeronautical Lab., 4455 Genesee St., Buffalo 21, N. Y.

Positions Wanted

By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The IRE publishes free of charge notices of positions wanted by IRE members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The IRE necessarily reserves the right to decline any announcement without assignment of reason.

Address replies to box number indicated, c/o IRE, 1 East 79th St., New York 21, N.Y.

REPRESENTATIVE / ENGINEERING

Engineer with electronic and executive experience; age 32; married with no family desires association with firm requiring representation western Canada or anywhere abroad. Position in engineering offering a challenge. Experience is sys-

(Continued on page 111A)

THE
EXCEPTIONAL
MAN

The combination of professional competence, leadership ability and business acumen required today for technical management responsibility calls for the Exceptional Man.

The Exceptional Man is rarely looking for a job . . . the job is looking for him.

Locating the Exceptional Man is our function.

Charles A. Binswanger ASSOCIATES
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EXECUTIVE SEARCH SPECIALISTS
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HONEYWELL AERO

Opportunity for growth

New and exciting programs, such as project Dyna Soar, have created these challenging career openings for engineers and scientists

Sr. Metallurgist—Exotic Metals to develop methods of brazing and solid state welding of exotic metals such as Beryllium; growing and fabricating single crystals of aluminum, Niobium and others for use in control devices for space vehicles requiring extreme accuracy; defining smoothness and waviness of surfaces and their measurement; surface treating to gain unique properties.

Sr. Chemist or Chemical Engineer with experience in vacuum evaporation, vapor reduction, and electro-deposition of coatings on metallic and non-metallic base materials or experience with any of the coating methods. Must be capable of developing processes providing uniform adherent deposits of materials having unique properties suitable to advanced gyro and circuitry development.

Sr. Systems Analyst. Must be well grounded in math and have 4 years' experience in analysis of aircraft stability and control. Familiar with both analog and digital computers and capable of applying various types of stability criteria such as phase amplitude plots, root locus, etc. Broad experience in circuit design and closed loop servo-systems.

Transistor Circuit Applications. Experience in audio frequency circuit design or servomechanisms, circuits utilizing transistors, diodes, transformers, magnetic amplifiers, etc. Familiarity with military design requirements desirable.

Electronics Packaging Engineer. 2 years' experience in the basic development of microminiature devices or design of one or more types of electronic components such as semiconductors or resistors. Experience with military hardware requirements desirable.

Senior Electronics Engineer to do analysis of complex servo systems and related circuitry. Must be able to translate analysis into circuitry. Four to six years' experience.

Send your resumé or request for further information to: Mr. Clyde Hansen, Technical Director, Aeronautical Division, 2616A Ridgway Road, Minneapolis 40, Minn. All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

To explore professional opportunities in other Honeywell operations, coast to coast, send your application in confidence to: Mr. H. G. Eckstrom, Honeywell, Minneapolis 8, Minnesota.

Honeywell

H HONEYWELL *Military Products Group*

Microwave Tube
ENGINEERS
OR
PHYSICISTS

Positions are available for senior development microwave tube engineers at our electronic tube plant in Montreal. Applicants should have a bachelor's degree and several years microwave tube development experience.

Substantial salaries will be paid to suitable applicants. Interviews will be arranged promptly and all replies will be on a confidential basis.

Please forward resume outlining education and experience to:

EMPLOYMENT ADMINISTRATOR
Canadian Marconi Company
2442 Trenton Avenue
Montreal 16, Quebec.

ENGINEERS . .

RESEARCH & DEVELOPMENT

Now is the time to investigate job opportunities with IFI if fou feel the need to reach out for a more promising and rewarding career.

Expansion of our Research and Development facilities offers challenging opportunities to creative Engineers in the field of Military and Commercial VHF and UHF electronic systems.

PROJECT ENGINEERS . . .

B.S. in E.E. or Physics. Prefer M.S. Minimum 7 years work background in UHF and VHF circuit development and extensive amplifier experience in the 50 to 1,000 MC range. Ability to provide technical direction and effective group management for all phases of prototype development, fabrication, testing, delivery and customer liaison.

SENIOR ENGINEERS . . .

B.S. in E.E. or Physics. Prefer M.S. Minimum 4 years broad technical background in circuit design and development in the 50 to 1,000 MC range.

ENGINEERS . . .

B.S. in E.E. or Physics. Several years experience in design development, analysis & investigation of electronic devices and systems in UHF and VHF range.

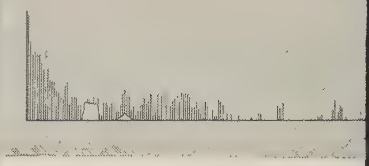
Salaries Commensurate With Ability. Many Benefits Including Profit Sharing Retirement Plan

Please submit resume in confidence to: Mr. J. V. HICKS, Personnel Manager

INSTRUMENTS
FOR INDUSTRY, INC.
101 New South Road, Hicksville
Long Island, New York

All qualified applicants considered regardless of race, creed, color or national origin.

ELECTROMAGNETIC COMPATIBILITY ANALYSIS



Here is your opportunity for professional growth in a challenging and extremely interesting field, as a member of an outstanding and stimulating scientific team. Armour Research Foundation, specialist in electronic interference evaluation, is now expanding its facilities and staff requirements in the area of Electromagnetic Compatibility Analysis. We are looking for qualified electronic engineers at all levels (B.S. through Ph.D.) for research and applied studies concerned with system analysis and performance prediction. Immediate openings are available at either our Chicago laboratories or at ARF's Electromagnetic Compatibility Analysis Center in Annapolis, Maryland for individuals with experience in one or more of the following fields . . .

RADAR
MICROWAVES
ANTENNAS
COMMUNICATION
PROPAGATION
CIRCUIT THEORY
MEASUREMENT AND ANALYSIS
TACTICAL EVALUATION

Staff members receive attractive salaries, up to four weeks vacation, generous insurance and retirement benefits and tuition free graduate study. All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin. Please reply in confidence to Mr. R. B. Martin.

ARMOUR RESEARCH FOUNDATION
OF ILLINOIS INSTITUTE OF TECHNOLOGY
TECHNOLOGY CENTER, CHICAGO 16, ILL.

Positions Wanted

By Armed Forces Veterans

(Continued from page 108A)

tems planning, research and production mostly in communications VHF (FM) and SSB telemetry. Member IRE. Overseas experience. British subject. Box 3935 W.

MANUFACTURERS REPRESENTATIVE

Phila. Pa. area (Pennsylvania, New Jersey, Delaware). Well established 10 years radio, television, electronic components. Member IRE. Excellent contacts purchasing and engineering level. Seeking additional quality component line. OEM & IND. Box 3936 W.

ELECTRONICS ENGINEER

Naturalized citizen leaving for Europe in March or April 1961 with wife who is a mathematician. Desires offers of full, part time, or commission assignment while in Europe on a 1 year leave of absence from the Operations Research Dept. of a major missile company. Speaks fluent Polish and German with good knowledge of French. Has good technical knowledge and experience in ground communications system, weapons systems study procedures, etc. BSEE, Oregon State College 1957. Ex-USAF Air and Airways Communications System Maintenance Chief. Box 3938 W.

COMMUNICATIONS ENGINEER

Desires position in Europe with progressive company in wire or radio communications projects. Experienced in systems operation and management and military R & D., MSEE., and advanced education; Professional Engineer; age 30; languages; highest security clearances; 7½ years military service (Signal Corps and ASA Officer). Box 3939 W.

COMMUNICATIONS SYSTEM ENGINEER

S.M.E.E. (MIT.) 10 years experience LOS, scatter, MUX, data communication in U.S. and overseas. Seeks challenging position in Europe. Foreign languages: French, German. Box 3944W.

EDUCATOR—ADMINISTRATION

Experienced teacher at graduate and undergraduate level in E.E. and physics. Ph.D. Specialist in planning of new programs. Desires position of responsibility where teaching, research, publications and organizational experience are fully utilized. Late 30's. East or West coast preferred. Box 3946 W.

ENGINEER—PILOT

BSEE. Member Tau Beta Pi. Age 32. 4000 hours pilot time including 1500 hours jet time. Presently Capt. USAF doing engineering/pilot duties. Experienced in airborne and ground navigation and communications equipment. Considerable management and supervisory experience. Interested in a challenging position which utilizes both engineering and pilot experience. Box 3947 W.

SUPERVISORY OR MANAGERIAL

Supervisory or managerial type position is desired; B.S. in mathematics and physics M.A. in administration and mathematics; 3 years industrial experience as supervisor of data reduction section; 6 years teaching experience, 4 at the

(Continued on page 112A)

Use Your IRE Directory— It's valuable

and the
universe shall
talk back...

Not necessarily in words and syllables but in electronic impulses, relayed by orbital, lunar and interplanetary communications systems.

Scientific advancement depends upon the ability of man to overcome the limitations of current knowledge. These limitations are being pushed aside at the Amherst Laboratories by new concepts for aerospace communications and instrumentation systems.

The role that microwave and millimeter wave technology will assume in future aerospace systems is being shaped through state-of-art advances achieved by our technical staff.

PROFESSIONAL STAFF AND MANAGEMENT OPPORTUNITIES *are unlimited for Physicists, Mathematicians and Electronic Engineers with advanced degrees and creative desire.*

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

You are invited to direct inquiries in confidence to Mr. H. L. Ackerman, Professional Employment,

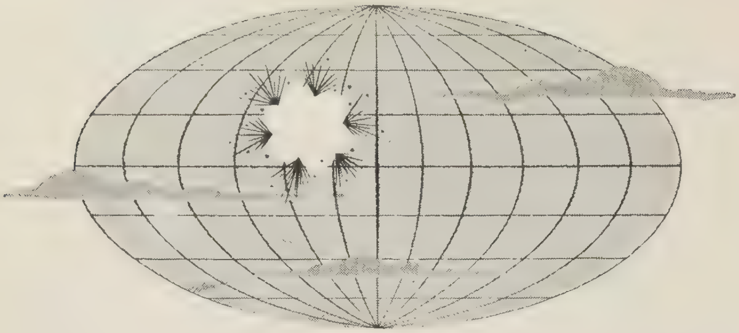
AMHERST LABORATORIES • 1181 WEHRLE DRIVE • WILLIAMSVILLE, NEW YORK

SYLVANIA ELECTRONIC SYSTEMS
Government Systems Management
for GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

"Shrinking the Universe . . . through Communications"

LIMITED WARFARE



A CONTINUING SEARCH FOR NEW KNOWLEDGE AT CORNELL AERONAUTICAL LABORATORY

Within recent months an ever increasing group of authoritative voices has been heard in a plea for enhanced ability to stamp out limited wars rapidly. Now recognized as that aspect of our preparedness in most critical need of technological advancement, the demand is being felt for new concepts in the areas of quick destruction, wide dispersal of small forces, highly creative use of camouflage, great mobility of troops and weapons, and the ability to capitalize on the cover afforded by night and bad weather. Today, as for some 15 years past, an important segment of CAL's technical effort is devoted to such tasks.

Current studies include tactical weapon systems, combat information and control systems, reconnaissance and surveillance, combat force mobility, CBR warfare, countermeasures, penetration aids, and new munitions concepts. CAL's searching look into the battlegrounds of the future includes more than a dozen research and development projects aimed at solving problems of limited warfare. They are problems that offer attractive opportunities for engineers and scientists. If you are interested in becoming a member of one of our small, closely knit research teams working on far-reaching scientific and technological programs, write today for a free copy of our factual, illustrated employment prospectus entitled "A Community of Science."

CORNELL AERONAUTICAL LABORATORY, INC.
of Cornell University
Buffalo 21, N.Y.

FREE REPORT

J. P. Rentschler L.W.
CORNELL AERONAUTICAL LABORATORY, INC.
Buffalo 21, New York
Please send me a copy of "A Community of Science."
Name
Street
City Zone State
☐ Please include employment information.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Positions Wanted

By Armed Forces Veterans

(Continued from page 111A)

college level and 2 in high school; 4 years experience as Executive Officer USNR; age 34; married with a family. Box 3948 W.

SERVO ENGINEER

BSEE. 1959, E.I.T. 1959; 7 months missile experience; 1½ years R&D design and checkout of fire control equipment. Additional graduate work in engineering and business. 7 months Naval Electronic School; 2 years as Naval Electronics Technician. Desires position in design or sales engineering with opportunity for advancement and further study. Age 27; married, 1 child. Willing to relocate. Box 3949 W.

COMPUTER ENGINEER

BEE., R.P.I. 1956, MSEE., M.I.T. 1958, MS. Physics, N.U. 1961. 5 years experience in computer systems and component development. Looking for challenging position in computer development, applications and/or sales. Desires New York City area. Willing to travel. Box 3951 W.

ELECTRICAL ENGINEER

Electrical Engineer desires challenging position in R&D work requiring professional competence, Experience in wire communications, data processing and transmission, programming, microwave systems, teaching, technical writing and supervision. Prefer area where graduate study is available. Will forward detailed resume on request. Box 3959 W.

SALES ENGINEER

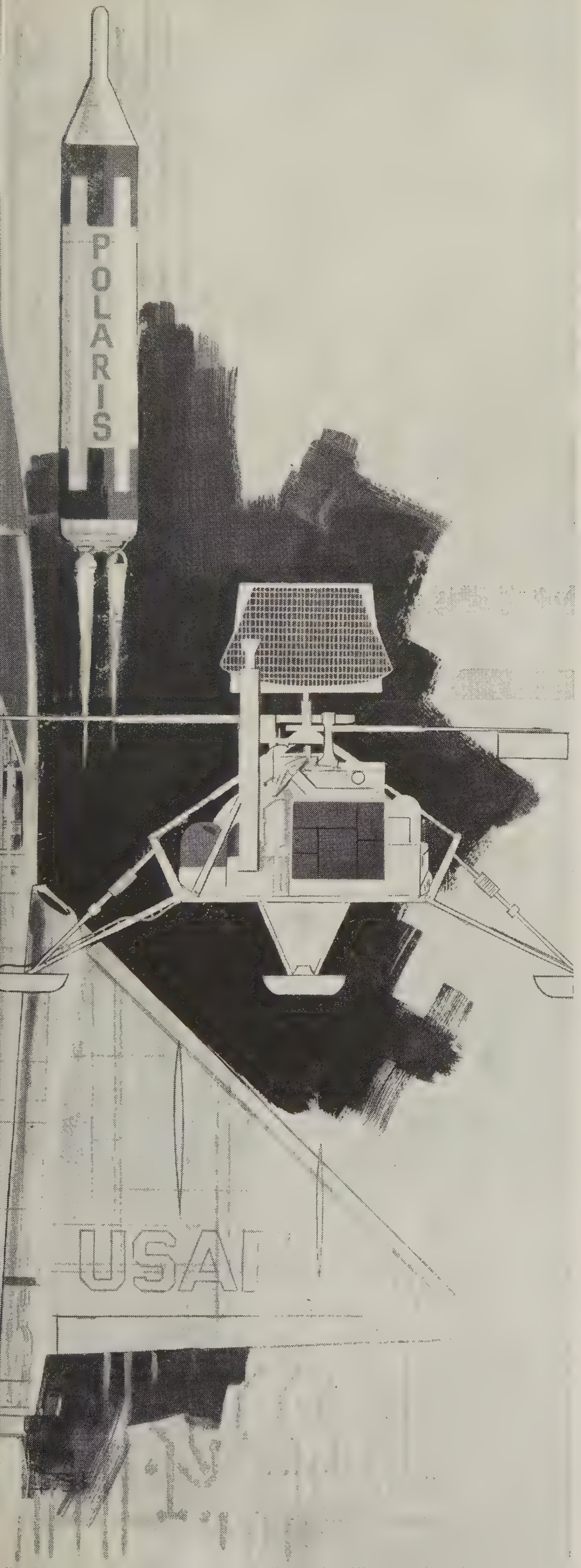
Desires position as sales engineer in southeastern U.S. Over 10 years in radio and electronics including radio and TV broadcasting, missile instrumentation and most recently, electro-mechanical instrumentation sales engineering. Box 3960 W.

WESCON EXHIBITORS' LIST

(Continued from page 100A)

Lockheed Aircraft Corporation	2711-2715
Lord Manufacturing Co.	907-909
Lumatron Electronics, Inc.	1017-1019
Luxo Lamp Corporation	308
MB Electronics	307-309
MM Enclosures, Inc.	5024
Mac Panel Company	4215
MacDonald & Company	4429
Magnasync Corporation	2811
Magnecraft Electric Company	3017
Magnetic Metals Company	4413
Magnetics, Inc.	1915-1917
Magtrol, Inc.	317
Mallory & Co., Inc., P. R.	1923-1925
Manufacturing Associates	3705
Marco Industries Co.	4130
Marconi Instruments	1408-1410
Marshall Industries	1814-1816
Master Specialties Co.	1303
McCoy Electronics Co.	1402
McGraw-Hill Publishing Co., Inc.	P-6—P-9

(Continued on page 114A)



Opportunities for

circuit designers

Requirements of new and continuing projects, such as Surveyor and supersonic interceptor fire control systems have created new openings for circuit designers. The engineers selected for these positions will be assigned to the following design tasks:

1 the development of high power airborne radar transmitters, the design of which involves use of the most advanced components,

2 the design of low noise radar receivers using parametric amplifiers, solid state masers and other advanced microwave components,

3 radar data processing circuit design, including range and speed trackers, crystal filter circuitry and a variety of display circuits,

4 high efficiency power supplies for airborne and space electronic systems,

5 telemetering and command circuits for space vehicles such as Surveyor and the Hughes Communication Satellite,

6 timing, control and display circuits for the Hughes COLIDAR* (Coherent Light Detection and Ranging).

In addition, openings exist for several experienced systems engineers capable of analysis and synthesis of systems involving the type of circuits and components described above.

If you are interested and believe that you can contribute, please airmail your resume to: **Mr. Robert A. Martin,** Supervisor, Scientific Employment, Hughes Aerospace Engineering Division, Culver City 68, California.

*Trademark H.A.C.

We promise you a reply within one week.

Creating a new world with electronics

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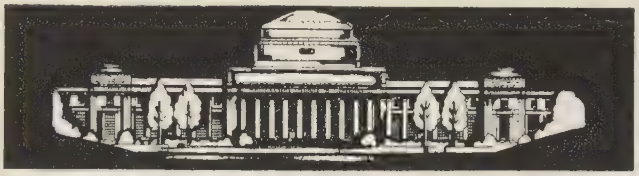
HUGHES AIRCRAFT COMPANY
AEROSPACE DIVISIONS

AT HUGHES, ALL QUALIFIED APPLICANTS WILL BE CONSIDERED FOR EMPLOYMENT WITHOUT REGARD TO RACE, CREED, COLOR OR NATIONAL ORIGIN.

An Invitation to • • •

PHYSICISTS
MATHEMATICIANS
AND ENGINEERS

from ■ **M. I. T.**



The Laboratory's staff of over 1000 under the direction of Dr. C. Stark Draper is engaged in the conception and perfection of completely automatic control systems for the flight and guidance of missiles and space vehicles. Its achievements include the Navy Mark 14 Gunsight, the Air Force A-1 Gunsight, Hermetic Integrating Gyros (HIG), and the Ship Inertial Navigation System (SINS). The Laboratory developed basic theory, components and systems for the Air Force THOR and, later, the TITAN missile.
The Laboratory also developed the Navy's POLARIS guidance system. Studies for NASA are currently being carried out.

- Graduate courses may be taken for credit while earning full pay.

Research and Development opportunities exist in:

- ANALYSIS OF SYSTEMS AND COMPONENTS
- HIGH PERFORMANCE SERVOMECHANISMS
- POWER SUPPLIES AND MAGNETIC AMPLIFIERS
- DIGITAL AND ANALOG COMPUTERS
- ELECTRO-MECHANICAL COMPONENTS
- TRANSISTOR CIRCUITRY AND PULSE CIRCUITRY
- RESEARCH, DESIGN AND EVALUATION OF GYROSCOPE INSTRUMENTS
- COMPUTER PROGRAMMING AND SIMULATOR STUDIES
- OPTICS, ASTRONAUTICS AND MANY OTHER AREAS

CALL OR WRITE HOWARD F. MILLER, PERSONNEL OFFICER

INSTRUMENTATION LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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UNIVERSITY 4-6900, EXT. 3544

★ All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

WESCON
EXHIBITORS' LIST

(Continued from page 112A)

McLean Engineering Laboratories	217
McMillan Industrial Corporation	2413
Mechtronics Corporation	3719
MeLabs	1122
Meller Company, Adolf	5133
Melpar, Inc.	4120
Menlo Park Engineering	2411
Mepco, Inc.	1121
Mesa Plastics Company	5021
Metcom, Inc.	1201
Methode Electronic, Inc.	4318
Michael, Inc., Claude	5020-5022
Micon Electronics, Inc.	216
Micro Electronics Corp.	321
Micro Gee Products, Inc.	2506-2508
Microdot, Inc.	1916-1918
Microlab	4306
Microtran Co., Inc.	411
Microwave Associates, Inc.	3118-3120
Microwave Development Laboratories, Inc.	3621
Microwave Electronics Corp.	1108
Midwestern Instruments	1522-1523
Millen Mfg. Co., James	1717
Miller Company, J. W.	401
Millivac Instruments, Inc.	911
Mincom Div., Minnesota Mining & Mfg. Co.	1806-1808
Minneapolis-Honeywell Regulator Co.	3501-3507
Mitchell Company, C. H.	306
Mitronics, Inc.	4519
Modular Electronics, Inc.	4416
Molectronics Corp.	2622
Molecu-Wire Corporation	4428
Monitor Products Company	1711
Moseley Company, F. L.	2010-2012
Mosley Electronics, Inc.	2517
Motorola Communications & Electronics, Inc.	1116
Motorola Semiconductor Products, Inc.	914-916
Moxon Electronics Corp.	1503
Mucon Corporation	4513
Mycalex Corporation of America	902-904
Mystik Adhesive Products, Inc.	5016
Narda Microwave Corporation	2407-2409
National Beryllia Corporation	4624
National Cash Register Company	1012-1014
National Connector Corporation	4213
National Radio Co., Inc., Subsid. of National Co., Inc.	1810
National Semiconductor Corp.	4212
National Vulcanized Fibre Co.	5123-5125
Nationwide Engineering Service, Inc.	4424
Navigation Computer Corp.	4515
New Hermes Engraving Machine Corp.	5007
Ney Company, J. M.	2210-2212
Nippon Electric Co., Ltd.	4109
Non-Linear Systems, Inc.	1518-1520
North American Electronics, Inc.	3509
North Atlantic Industries, Inc.	2812-2814
North Electric Company	2502-2504
Nurches Company, Paul	2707

(Continued on page 116A)

Ramo-Wooldridge designs and produces data processing systems, computers, display devices, man-machine communication consoles, and related peripheral equipment for military and commercial applications.

Select openings exist in systems analysis and applications, computer programming, equipment design and applications engineering.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin. Write for our free career brochure **An Introduction to Ramo-Wooldridge.** Address Mr. Theodore Coburn at **Ramo-Wooldridge,** a Division of Thompson Ramo Wooldridge Inc., 8433 Fallbrook Avenue, Canoga Park, California.

WESCON EXHIBITORS' LIST

(Continued from page 114A)

Nylok Western	4426
Offner Electronics, Inc.	1513-1514
O'Halloran Associates	2416
Ohmite Mfg. Co.	1601-1603
Omtronics Mfg., Inc.	4216
Optical Coating Laboratory	4908
Optimized Devices, Inc.	1210
Osborne Electronics Corp.	612
Oster Mfg. Co., John	3004
P C A Electronics, Inc.	1423
PIC Design Corporation	1404
PRD Electronics, Inc.	2109-2110
Pacific Coast Electronics Corp.	1226
Pacific Resistor Company	4206
Pacific Scientific Company	311
Pacific Semiconductors, Inc.	2111-2112
Packard Bell Computer Corp.	2617-2618
Packard Bell Electronics Corp.	4202
Palo Alto Engineering Company	512
Panduit Corporation	817
Panoramic Electronics, Inc.	3202-3204
Parker Seal Company	4828
Patrick Associates, Inc., Loren	5127
Penta Laboratories, Inc.	1115
Perfect Gear and Instrument Corp.	316
Perfection Mica Co., Magnetic Shield Div.	4606
Perkin Electronics Corp.	516-518
Perkin-Elmer Corp.	119
Perlmuth Electronic Associates, Inc.	2211
Phaostron Instrument & Electronic Co.	1401-1405
Philbrick Researches, Inc., George A.	4204
Philco Corporation, Lansdale Div.	919-921
Phillips Control Co., Div. of Phillips-Eckardt Electronic Corp.	419
Photo Chemical Products of California, Inc.	4705
Photocircuits Corporation	2624
Piddington & Associates, Ltd.	5029
Plastic Capacitors, Inc.	615
Plastic Products Div., International Resistance Co.	1421
Plastoid Corporation	4727
Polarad Electronics Corporation	1911-1913
Pomona Electronics Co., Inc.	2709
Potter Aeronautical Corporation	4506
Potter & Brumfield	2206-2208
Potter Company	1205
Potter Instrument Co., Inc.	101-103
Power Designs, Inc.	2705
Power Sources, Inc.	2816-2818
Powertron Ultrasonics Corp.	5111
Precision Instrument Co.	913-915
Precision Scientific Company	4504
Premier Metal Products Company	4707-4709
Prentice-Hall, Inc.	P-15
Price Electric Corporation	2806
Prodelin, Inc.	2701
Prudential Industries, Inc.	3606-3608
Pulse Engineering, Inc.	2808
Pyle-National Company	1213
Pyrofilm Resistor Co., Inc.	2810
Quan-Tech Laboratories, Inc.	1020-1022
RS Electronics Corp.	3322
Radiation at Stanford	4205-4207
Radiation, Inc.	4209
Radiation Materials, Inc.	4713
Radio Corp. of America	715-721, 616-622
Radio Frequency Laboratories, Inc.	2912-2914
Ransom Research, Inc.	4211
Rantec Corporation	2510-2512
Raychem Corporation	5008-5010
Raytheon Company	3404-3422
Raytheon Company, Production Equipment Dept.	4823
Reed Instrument Bearing Co., Div. of SKF Industries, Inc.	4525
Reeves Instrument Corp.	3214-3218
Reeves Soundcraft Corp.	2312
Reid Brothers Co., Inc.	4425
Rese Engineering, Inc.	3721
Rheem Mfg. Corp.	901-905
Riedel & Company, M. W.	4113-4115
Rimak Electronics, Inc.	4813
Robinson & Middy Associates	4105
Rockbestos Wire & Cable Co., Div. of Cerro Corp.	4326
Rogers Publishing Co.	P-14
Rohde & Schwarz Sales Co., Inc.	2526-2528
Rosan, Inc.	4906
Ross Company, Milton	4528
Rototest Laboratories, Inc.	315
Rotron Mfg. Co., Inc.	3006-3008
Rowan Controller Company	221

(Continued on page 118A)

ENGINEERS • SCIENTISTS

environment

FOR **m**aximum

responsibility

Broad technical objectives at Electro-Mechanical Research, Inc. (e.m.r), including the development of the test instrumentation subsystem for the Dyna-Soar manned space glider, provide an *environment for maximum responsibility* for senior engineers and scientists.

e.m.r is engaged in the conception, design and construction of airborne and ground telemetry and data processing equipments. Fundamental investigations are also being made into advanced electronic systems.

At e.m.r, growth is planned and diversified, research is company-sponsored, bringing exceptional opportunity to engineers and scientists with broad capabilities and a sincere desire to advance the state of the art.

Immediate career incentives for SYSTEM DESIGN SPECIALISTS

Opportunity for broad state-of-the-art design responsibilities. If you have five years' hardware design experience (magnetics and solid state circuitry, RF transmitters, and semi-conductor applications, DC through UHF) — like "real" engineering, not administration, in a technically demanding atmosphere, you will want to associate with e.m.r. Remuneration based on your engineering capabilities and your ability to think—not your knowledge of "paper shuffling."

Please direct inquiries in confidence to
ROLAND E. HOOD, JR.,
PERSONNEL MANAGER, SYSTEMS DIVISION.

e·m·r

electro-**m**echanical **r**esearch, inc.
P.O. Box 3041, Sarasota 1, Florida
exploration . . . **m**anufacture/**r**eliability

Qualified applicants considered without regard to race, creed, color or national origin.

3-nation net into space

Goldstone, Calif., Woomera, Australia. Krugersdorp, South Africa.

Three different parts of the world thousands of miles from each other. Yet drawn together in a new and unique communications net: the Deep Space Instrumentation Facility.

DSIF is under the technical direction of Cal Tech's Jet Propulsion Laboratory for the National Aeronautics and Space Administration. Staffed and run by the host countries, the tracking stations will have 85-feet-in-diameter antennas, capable of transmitting and receiving. These giant, revolving steel and aluminum saucers are able to send and receive signals hundreds of millions of miles to and from space.

It was at Goldstone that JPL bounced signals off the planet Venus—85-million miles away. This two-month experiment gave us valuable data about the distance and surface of Venus and helped maintain the United States as the leader in planetary radar astronomy.

Communicating with deep space probes is just one function of the three stations of DSIF. Their primary job is tracking all the spacecraft designed by JPL to fly-by, orbit, and land on the moon and planets. Because the stations provide 360° coverage around the earth, one of the three will always be in contact with each distant spacecraft in flight and after it arrives.

DSIF is an essential participant in the many space projects at JPL. Ranger, Surveyor, Mariner. Some of these spacecraft are imminent. Others are on JPL blackboards. All will bring new technologies, new knowledge of our planets and the topless universes beyond, and a still greater understanding of our own small world.

To carry on these vital projects, we need top scientists and engineers of many different disciplines. We need people who love their work, who want to know, and want to participate in the exploration of other worlds. If you believe you're qualified, then come explore with us. Write today.

JET PROPULSION LABORATORY
4804 Oak Grove Drive, Pasadena, California
Operated by California Institute of Technology for the National Aeronautics and Space Administration

Jpl

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

WELCOME ABOARD!

Responsible positions available for

STATIC INVERTER RESEARCH SPECIALISTS

Ph.D. or M.S.. with two or more years of experience, to participate in an advanced design and development program utilizing transistor and silicone-controlled rectifiers.

SOLID STATE PHYSICISTS

Ph.D. or equivalent, with experience in: preparative techniques and measurements of physical properties and a working knowledge of bond theory and its application to solid state devices; or in design of solid state devices.

Astropower is an expanding propulsion R & D firm located in the ideally-situated research center at Newport Beach, California, one of the finest recreation areas in the world. Superior employee benefits. Submit resumes to Dr. George Moe, Vice President, Research. Qualified applicants will receive consideration without regard to race, creed or national origin.

ASTROPOWER, INC.

A subsidiary of Douglas Aircraft Co.

2968 Randolph Avenue
Costa Mesa, California

WESCON
EXHIBITORS' LIST

(Continued from page 116A)

Royal McBee Corporation	4520
Royco Instruments, Inc.	110
Rush & Key Electronics, Inc.	1721, 1411
Rutherford Electronics Co.	1501-1502
Sage Laboratories, Inc.	4232
St. Regis Paper Company	5121
Sams and Company, Inc., Howard W.	P-13
San Fernando Electric Mfg. Co.	1903
Sanborn Company	2014-2016
Sanders Associates, Inc.	2523-2525
Sangamo Electric Company	2207-2209
Sarkes Tarzian, Inc.	505-507
Scientific-Atlanta, Inc.	3522
Scientific Engineering Labs.	5132
Scopes Company, Inc.	207
Sealectro Corporation	716
Selectrons, Ltd.	4827
Semcor Solid State Div., Nuclear Corp. of America	2120-2121
Sensitive Research Instrument Corp.	2113-2114
Servo Corporation of America	4509-4511
Servonic Instruments, Inc.	4107
Shelton Div., United Shoe Machinery Corp.	4722-4724
Sherold Crystals, Inc.	2819
Shielding, Inc.	2511-2513
Shoemaker & Associates, H. M.	711
Sibley Company	4430
Sierra Electronic Corporation, Div. of Philco Corp.	2006-2008
Silicon Transistor Corp.	1224
Simplex Wire & Cable Co.	4423
Simpson Electric Company	1704-1706
Sippican Corporation	4422
Skydyne, Inc.	4817-4819
Sliding Mechanisms, Inc.	4910
Slip Ring Co. of America	206
Smith-Florence, Inc.	1102-1104
Smith, Inc., Herman H.	1611
Snitzer Co., T. Louis	3112
Sola Electric Co., Div. of Basic Products Corp.	2321-2323
Solid State Products, Inc.	1119
Southco Div., South Chester Corp.	4804
Southern Electronics Corp.	1723
Space Age News	P-20
Space Technology Laboratories, Inc.	209-211
Spaulding Fibre Co., Inc.	5134
Spectra-Strip Wire & Cable Corp.	4726
Spectrol Electronics Corp.	602-604
Spectrolab, Div. of Textron Electronics, Inc.	313
Sperry Rand Corporation	3111-3121
Sprague Electric Company	1904-1908
Standard Pressed Steel Company	4717
Standard Wire & Cable Co.	4630
Sterling Precision Corp.	918
Stevens-Arnold, Inc.	2522-2542
Stevens Mfg. Co., Inc., George	4618
Stewart Engineering Company	123
Stewart Stamping Co.	4708
Stoddart Aircraft Radio Co., Inc.	205
Stone & Smith, Inc.	5107-5109

(Continued on page 120A)

PROJECT ENGINEERS AND SECTION HEADS

To assume major responsibilities in

- Computer Control
- PCM Telemetry
- Automatic Checkout & Monitoring
- Analog to Digital Conversion
- Electro-medical Instrumentation

EXCELLENT SALARIES . . .
. . . STOCK OPTIONS

Applicants must have design experience in transistor circuits for data systems, computers, linkages, telemetry or medical electronics and have delivered hardware.

Join our dynamic staff of 800 employees by writing:
IVAN P. SAMUELS

Epsco incorporated

275 Massachusetts Avenue
Cambridge, Massachusetts

All qualified applicants considered without regard to race, creed or national origin.

THERE IS SOMETHING NEW UNDER THE SUN

Yes, there *is* something new under the sun. Science is proving this every day. With new discoveries. New explorations. New concepts.

Nowhere is this more evident than in the field of technology. For example: On the drawing boards of Lockheed Scientists and Engineers, new designs are constantly being born—designs in Spacecraft and Aircraft that will reinforce and enlarge our growing knowledge of Outer Space.

These new designs are rapidly developing. And their number is rapidly increasing. The pace is fast. Yet it needs to become faster. To keep pace, Lockheed needs more Scientists, more Engineers. Result? The future for Lockheed was never more promising—the opportunities never greater.

Lockheed feels that trained men will do well to examine thoughtfully the Company's current openings. Notable among these are: Aerodynamics engineers; thermodynamics engineers; dynamics engineers; electronic research engineers; servosystem engineers; electronic systems engineers; physicists (theoretical, infrared, plasma, high energy, solid state, optics); hydrodynamicists; ocean systems scientists; physiopsychological research specialists; electrical-electronic design engineers; stress engineers; and instrumentation engineers.

Scientists and Engineers: To learn more about the opportunities at Lockheed, write Mr. E. W. Des Lauriers, Manager Professional Placement Staff, Dept. 1808, 2402 No. Hollywood Way, Burbank, California. All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin. U.S. citizenship or existing Department of Defense industrial security clearance required.

LOCKHEED CALIFORNIA DIVISION

ENGINEERS • SCIENTISTS

a technical adviser's seat at the conference table

...where the requirements of the aerospace control environment are defined—decisions implemented

This seat is reserved for MITRE, Technical Adviser to the Air Force for command and control systems.

Electronic Systems must meet the challenge to command posed by present and future weapons, aerospace vehicles and widely dispersed forces.

MITRE works with the Air Force in planning and developing these systems. The job demands application of the most advanced command and control technology.

Many technical disciplines are pursued with a scientific objectivity engendered by the corporation's nonprofit status and the clearly defined programs established bilaterally with the Air Force Electronics Systems Division.

Specifically, MITRE engages in:

...Advance conceptual planning
...Specification of individual system requirements
...Intersystem engineering
...Research and experimentation to generate new command and control techniques

Engineers and scientists interested in the new field of command and control technology are invited to inquire about openings in:

- **Operations Research**
- **System Analysis**
- **Communications**
- **Econometrics**
- **Human Factors**
- **Radar Systems and Techniques**
- **Advanced System Design**
- **Air Traffic Control System Development**
- **Computer Technology**
- **Mathematics**
- **Antenna Design — Microwave Components**

Write in confidence to: VICE PRESIDENT — TECHNICAL OPERATIONS

THE MITRE CORPORATION

Post Office Box 208, 4-MV—Bedford, Massachusetts

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

WESCON
EXHIBITORS' LIST

(Continued from page 118A)

Sunbank Electronics, Inc.	4502
Superior Electric Co.	1312-1314
Surprenant Mfg. Co.	4816-4818
Switchcraft, Inc.	1510
Sylvania Electric Products Inc.	3302-3312, 3201-3212
Synthane Corporation	4716
Systron-Donner Corporation	2611-2613
Tally Register Corporation	2516
Tang Industries, Inc.,	4415
Tech-Ohm Electronics, Inc.	4405
Tech-Ser, Inc.	2213-2215
Technical Appliance Corp.	409
Technical Devices Co.	4802
Technical Products Co.	617
Technical Sales Corp., Subsid. of Graphic Controls Corp.	3716
Technical Wire Products, Inc.	215
Technology Instrument Corp. of California	1506-1508
Tektronix, Inc.	1726-1728, 1823
Telecomputing Corp.	2022-2024
Telerad Div. of The Lionel Corp.	3605-3607
Teletype Corporation	4418-4420
Telex, Inc.	2503-2505
Telonic Industries, Inc.	2813-2815
Temperature Engineering Corp.	4922
Tenney Engineering, Inc.	4222
Tensolite Insulated Wire Co., Inc.	4608
Texas Instruments Incorporated	3014-3022
Thermador Electrical Mfg. Co.	1811
Thermal Wire of America	4622
Thomas & Betts Company	418-420
Thomas Electronics, Inc.	4406
Thomas & Skinner, Inc.	1819
Thompson Publications, Inc. F. D.	P-10
Thompson Ramo Wooldridge, Inc., Dage Div.	3215
Thorson Company	4224
Tinsley Laboratories, Inc.	4501
Topatron, Inc.	2616
Torrington Mfg. Co.	4117
Trans-Sonics, Inc.	4414
Transdata, Inc.	114
Transformer Engineers	1705
Transistor Specialties, Inc.	4101
Transitron Electronic Corp.	3502-3504
Tri Metal Works, Inc.	5117
Tri-State Supply Corp.	5105
Trio Laboratories, Inc.	917
Triplett Electrical Instrument Co.	511
Tru-Connector Corp.	4328
Tru-Ohm Products Div., Model Eng. & Mfg., Inc.	1511
Trygon Electronics, Inc.	4119
Tung-Sol Electric, Inc.	1807-1809
Tur-Bo Jet Products Co., Inc.	3007
Ultek Corporation	4320
Ultrasonic Industries, Inc.	4526
Ultronix, Inc.	3206
Ungar Electronic Tools, Div. of Eldon Industries, Inc.	4815
Unholtz-Dickie Corporation	4324
Union Switch & Signal, Div. of Westinghouse Air Brake Co.	3101-3103

(Continued on page 126A)

REPUBLIC AVIATION NEWS

NEW RECONNAISSANCE ROLE FOR "ELECTRONIC PLANE"

NEW PRIME CONTRACT AWARDED REPUBLIC CREATES DEMANDING ASSIGNMENTS FOR EE's & PHYSICISTS

The development of a reconnaissance capability for Republic's F-105D marks the first "marriage" of an all-weather reconnaissance system with an all-weather airborne weapon system. The one-man F-105D has already earned the title of the "world's first electronic plane," because its integrated complex of electronic systems permits it to be almost fully automatic. Flight control, navigation, target seeking, identification and tracking, fire control for diverse weapons are all automatically controlled.

With the addition of a sophisticated reconnaissance system the F-105D becomes a flying electronic platform. System design and analysis of the new reconnaissance package and its aerospace ground support present stimulating new challenges to electronic engineers and physicists. Optimum integration of the whole electronic complex offers unique problems.

SENIOR & INTERMEDIATE POSITIONS NOW OPEN TO ENGINEERS (EE) AND PHYSICISTS, TO PERFORM SYSTEMS DESIGN, ANALYSIS, TEST AND RELIABILITY ENGINEERING ON:

Radars (front & side looking)
Infrared Systems
Antennas, Radomes
Data Links
Digital Computers
Flight & Fire Control Systems
High Speed Tape Recorders
Optical Systems
Aerospace Ground Support Equipment

These opportunities are at 2 Republic locations: Mineola and Farmingdale, Long Island. For further information, write in confidence to:

▸ Mr. George R. Hickman
Technical Employment Manager,
Dept. 14H
Republic Aviation Corporation
Farmingdale, Long Island, New York

▸ Mr. Paul Hartman
Technical Employment, Dept. 14H-A
Missile Systems Division
Republic Aviation Corporation
223 Jericho Turnpike
Mineola, Long Island, N.Y.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

All Republic programs are backed up by the new **Paul Moore Research & Development Center**, an integrated complex of eight laboratories dedicated to the advancement of all aspects of aerospace technology.

REPUBLIC
AVIATION CORPORATION

A frank statement about recruitment

Daily changes in defense requirements of necessity affect manpower needs. The national good makes it imperative that critical programs be promptly staffed. Where new jobs cannot be filled from within, and there is no time to train young men, the only recourse is recruitment.

Recruitment is hard, expensive, frustrating work. Worse still, individual employer efforts are often labeled "piracy." And yet the job must be done.

Career Centers, which combine the recruiting efforts of many employers, provide a new approach to these problems. First, the employers may initiate no contact with a man. The man must come to them. Second, a great deal of time and expense is saved for all by having everything under one roof at one time.

Eighty-seven industrial and government employers and more than 10,000 engineers and scientists have participated in Career Centers during the past year in New York City, Los Angeles and Washington, D. C.

President, Careers Incorporated

COMING CAREER CENTER SESSIONS

SAN FRANCISCO — August 22 - 25, 1961
NEW YORK CITY — October 10 - 13, 1961
WASHINGTON, D. C. — December 12 - 14, 1961
NEW YORK CITY — March 26 - 29, 1962

Career Centers are a service of Careers Incorporated, 770 Lexington Avenue, New York 21, N. Y. Publishers of "Career: for the College Man" and "Career: for the Experienced Engineer and Scientist."

WESCON
EXHIBITORS' LIST

(Continued from page 120A)

United Catalog Publishers, Inc.	P-22
U. S. Stoneware Co., Alite Div.	1202-1204
United Transformer Corp.	1613
Unitek Corporation	4808-4810
Universal Electronics Co.	807
Universal Instruments Corp.	4932-4934
Universal Mfg. Co., Inc.	4532
Utica Drop Forge and Tool Div.	5031

Vaco Products Co.	412
Vacuum Apparatus Co.	113
Vacuum-Electronics Corp.	120-122
Vacuum Technology, Inc.	1214
Van Groos Company	1920
Vari-L Company, Inc.	4312
Varian Associates	2009-2017
Varo, Inc.	3609-3611
Vector Electronic Co., Inc.	1824, 1927
Veeder-Root, Inc.	3617-3619
Verco, Inc.	4210
Victor Adding Machine Co.	3208
Vidar Corporation	112
Viking Industries, Inc.	1815-1817
Vitramon, Inc.	1818
Vitro Electronics	1219-1221
Vogue Instrument Corp.	3723

Wagner, L.	5030
Wales Strippit, Inc., Unit of Houdaille Industries, Inc.	5120-5122
Walkirt Company	1725
Ward Leonard Electric Co.	509
Waterman Products Co., Inc.	1406
Wave Particle, Div. of Ramage & Miller, Inc.	4214
Weart Brothers, A. W.	4208
Weckesser Co., Inc.	4822
Weightman & Associates	1708
Weller Electric Corp.	5118
Wesrep Corporation	1318
Western Devices, Inc.	5009-5013
Western Gear Corporation	1001-1003
Western Gold & Platinum Co.	4712
Western Transistor Corp.	4220
Westinghouse Electric Corp.	3515-3521, 3616-3622
Westline Products Div., Western Lithograph Co.	4807
Westron Sales & Engineering	3511
White Industrial Div., S. S.	5128
Wiley & Sons, Inc., John	P-16
Wilkinson Co.	4825
Wiltron Company	1212
Winchester Electronics, Inc.	2205
Wire Co. of America	4710
Wright Engineering Co.	2115-2117
Wright Machinery Co., Div. of Sperry Rand Corp.	3717
Wyle Laboratories	4518

Xcelite, Inc.	402

Yardney Electric Corp.	3402
Yokogawa Electric Works, Inc.	4111

Zero-Max Company	416
Ziff-Davis Publishing Co.	P-21
Zimmerman Company, W. E.	314
Zippertubing Co.	5113

DEATH
WATCH
on a Killer...

In September 1959, "Hurricane Hunters" of the U. S. Navy kept a 24-hour vigil on Hurricane Gracie. They took 30,000 frames of pictures in and around this severe storm — kept the Joint Hurricane Warning Center constantly alerted to Gracie's feminine eccentricities. As a result of this dangerous death watch, only 22 deaths were attributed to Gracie and property damage was minimal.

Soon the romantic "Hurricane Hunters" will be phased out — their observations superseded by highly advanced electronic equipment. Similar changes will be made in other areas as the national weather services utilize the latest technology (including weather satellites) to improve all aspects of weather observation and forecasting.

To speed these changes the Weather System Center is assisting in the development of a host of new techniques and electronic equipment for weather observation, data transmission, data processing and display. Experimental weather systems will be operated to test out these techniques and equipment; a high-speed communication system developed.

Because of major expansions in this project, the Weather System Center now has a number of very attractive openings for ELECTRICAL ENGINEERS at both supervisory and operational levels. All of these positions offer unusual challenge and the opportunity to build a satisfying career in a field with outstanding growth potential.

* * *

SUPERVISORY POSITIONS for: Engineering Supervisor • Senior Test Engineer • Station Engineer • Staff Test Engineer • Data Transmission Specialist.

* * *

Other opportunities for: Radar Engineer • Display Engineer • Computation Analyst • System Analyst • System Engineer • Digital Communication Equipment Engineer • Weather Observing Equipment Engineer • Meteorological Analyst • Technical Editor • Technical Writer • Electronic Technician.

* * *

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

* * *

Please write to Mr. F. J. Finch, Personnel Department.

UAC WEATHER
SYSTEM CENTER

UNITED AIRCRAFT CORPORATION / 400 MAIN STREET, EAST HARTFORD 8, CONN.

HEAD RADAR SECTION

Cornell Aeronautical Laboratory has an attractive opening as technical supervisor of a group involved in experimental and theoretical studies of the physics of radar. Strong emphasis is placed on investigation of the characteristics and signatures of radar echoes.

The position holds outstanding opportunities for further development of already successful and continuing research programs.

Here is a challenging job with a firm research basis, coupled with the freedom to expand. **Write to Mr. J. P. Rentschler, Cornell Aeronautical Laboratory, Inc., Buffalo 21, New York.**

CORNELL AERONAUTICAL LABORATORY, INC.
of Cornell University • Buffalo 21, New York

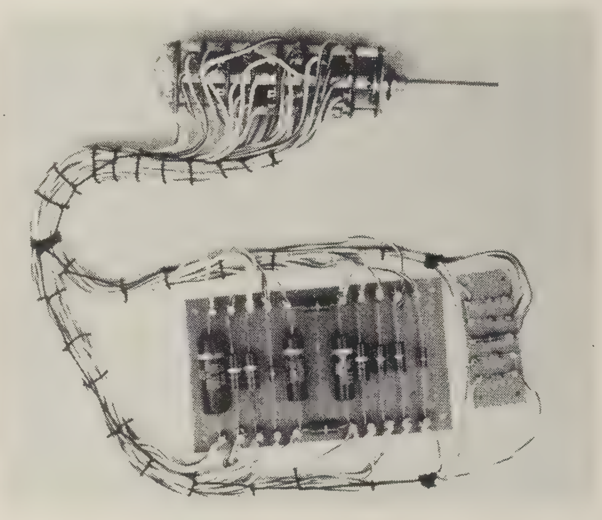
All qualified applicants will receive consideration without regard to race, creed, color or national origin.

NEWS New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

Monoplanar Switch

The Ucinite Co., 459 Watertown St., Newtonville 60, Mass., announces availability of its new Uniplane switch kits, from which more than 1000 multipole, multiposition, multicircuit selector switch combinations can be assembled on a single flat surface. All components are assembled and all inter-connections are made on this same surface.



Conventional Multi-Deck Rotary

Join Sanders Associates in Nashua, New Hampshire

"The company is interested in NEW ways of doing things"..."work is carried on above the average level"..."circuit design here goes all the way from DC through microwave"—

—so say Engineers who have joined Sanders Associates in the past few months.

Such progressive philosophy has led to this young company's growth from 11 engineers to 1800 employees in only 10 years, with a current contract backlog of over $50 million.

Still further expansion is planned for pioneering programs in many advanced areas including phased array radar, pulse doppler radar systems, space radar and communications systems.

KEEP YOUR LEARNING CURVE UP!

If you are interested in working on the threshold of the state-of-the-art, untethered by conventional techniques, send a resume now to R. W. McCarthy.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

Opportunities are available now for:

RECEIVER DESIGN ENGINEERS

3 to 8 years experience. For design and development of receivers for military applications. Experience should include design of low noise front ends, IF strips, AGC circuitry and application of image rejection techniques. All transistorized. BS in EE or Physics.

TRANSISTOR CIRCUITRY CONSULTANT

To provide technical guidance at the Corporate level on a wide variety of transistor circuit design problems. Requires ability to design detailed circuits rapidly.

CIRCUIT DESIGN ENGINEERS

To translate conventional wire circuits into flexible and/or rigid printed circuitry and to design circuitry layout and approaches for printed circuits. A prime requisite is a keen and imaginative mind and native ingenuity to provide unique solutions to new problems in the field. Requires EE, ME or ChE with printed circuit background.

TRANSMITTER DESIGN ENGINEERS

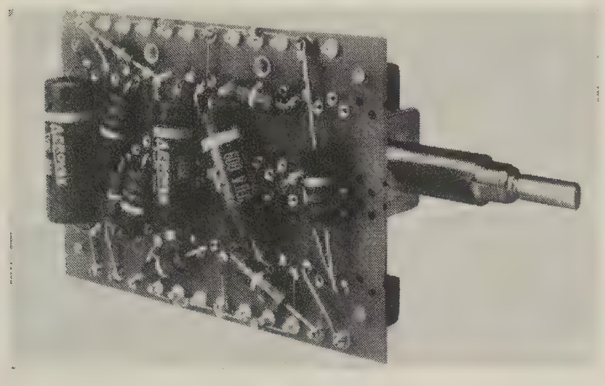
For design and development of transmitters, VHF-UHF and microwave frequency range, tubes, pulse modulators, power in excess of 1 kilowatt for military and airborne applications.

SANDERS ASSOCIATES, INC.
NASHUA, NEW HAMPSHIRE
(In the New Hampshire hill country about an hour from downtown Boston)

The Dot® Uniplane monoplanar switch and all the circuitry associated with it can be put together in three steps that are said to eliminate 75% of the time, labor and materials required to assemble an old style multi-deck selector-plus-cable-plus-terminal-board assembly. In the three-step process, components are soldered into position, the shaft length is adjusted and the drive mechanism is attached in any one of three orientations.

Since all switch elements and components are mounted on a single, flat layout they are completely accessible and the assembly is greatly improved in appearance over older types. It is also smaller by 30% to 80%.

Reliability is increased by the 50% to 70% reduction in the number of solder joints and by the "conservative" mechanical action of the switch, which eliminates many of the sources of rotary selector-switch failure.



Single Plane Type

With the kit, engineers, who have been hitherto prevented (by the high cost and long time-cycle of custom manufacture) from employing monoplanar switches on prototypes and short production runs may now obtain them from stock at stock-model prices.

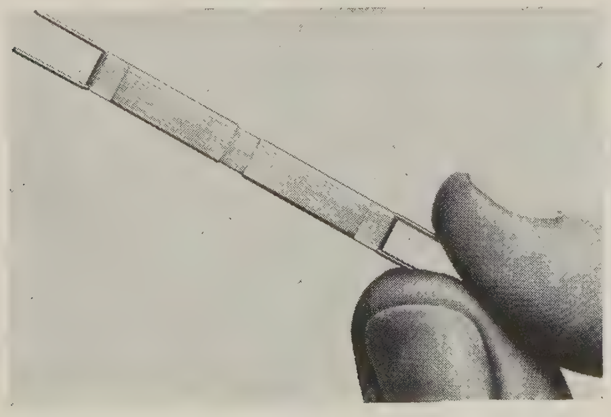
For longer production runs, or for very critical requirements, custom versions of the basic Uniplane switches will be made by the manufacturer. In these designs, the entire circuit is printed on the switch plane, further reducing cost and increasing reliability.

The compactness and flexibility of form factor of the switch makes it possible to install it in a wide variety of positions and in places too small or the wrong shape for older types. This versatility simplifies panel and cabinet design and so affords further savings. It also affords the engineer or designer a new degree of freedom in the design of the equipment in which the switch is employed.

For further information, write Ken Bushnell at the firm. Price of the kit: $23.75, f.o.b., Newtonville, Mass.

Instant Emission By New Cathode

The "fastest heating cathode ever produced," the Harp Cathode has been announced by **Amperex Electronic Corp., Power Tube Div.,** 230 Duffy Ave., Hicksville, L. I., N. Y. Capable of delivering full power in 100 milliseconds, the Harp Cathode will be incorporated in a full line of Amperex tubes to be used as RF power output stages in transistorized mobile and airborne equipment.



(Continued on page 131A)

Why don't you **Talk** with Westinghouse

where the door is open to Your Professional Growth

Recent engineering graduates, whose job expectations have not been fulfilled—should consider Westinghouse-Baltimore, where engineering careers thrive on challenging projects carried out in the finest company-owned facilities under an engineer-oriented management. The Westinghouse Graduate Study Program will enable you to combine stimulating project work with advanced technical studies at The Johns Hopkins University or the University of Maryland. You'll find that *your career* potential is unlimited at Westinghouse!

Current opportunities include:

Electronic Countermeasures
Electronic Counter-countermeasures
Microwave Techniques
Radio Frequency Control
Pulse Circuitry
Semiconductor Circuitry
Liaison & Field Engineering

All qualified applicants will continue to receive consideration for employment without regard to race, creed, color, or national origin.

Send resume to: Mr. J. F. Caldwell, Dept. 419

Westinghouse
BALTIMORE
P. O. Box 746 Baltimore 3, Maryland
AIR ARM • ELECTRONICS • ORDNANCE

Increased technical responsibilities in the field of range measurements have required the creation of new positions at the Lincoln Laboratory. We invite inquiries from senior members of the scientific community interested in participating with us in solving problems of the greatest urgency in the defense of the nation.

RADIO PHYSICS and ASTRONOMY

RE-ENTRY PHYSICS

PENETRATION AIDS DEVELOPMENT

TARGET IDENTIFICATION RESEARCH

SYSTEMS: Space Surveillance
Strategic Communications
Integrated Data Networks

NEW RADAR TECHNIQUES

SYSTEM ANALYSIS

COMMUNICATIONS: Techniques
Psychology
Theory

INFORMATION PROCESSING

SOLID STATE Physics, Chemistry, and Metallurgy

A more complete description of the Laboratory's work will be sent to you upon request.

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Research and Development
LINCOLN LABORATORY
Massachusetts Institute of Technology
BOX 16
LEXINGTON 73, MASSACHUSETTS

Professional Opportunities Are Available For

Electrical Engineers

with interest and experience in the following fields:

- Design and Development of:
  Industrial Electronics and Power
  Controls and Instrumentation
  Electronics
- Operation & Maintenance of
  Nuclear Devices

For information please write to:
Personnel Manager
Brookhaven National Laboratory
UPTON, LONG ISLAND, N. Y.

BROOKHAVEN NATIONAL LABORATORY · UPTON-NEW YORK
A Center for Nuclear Research and Development

Attending WESCON? Contact us to arrange San Francisco Bay interviews

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ENGINEERS
CALIFORNIA

offers you and your family

- A world center of the electronic industry for CAREER ADVANCEMENT
- The High Sierra and the Pacific Ocean for RECREATION
- Some of the nation's finest public schools for your CHILDREN
- World Famous Universities for ADVANCED STUDY
- MAJOR CULTURAL CENTERS

while living in such places as
Exciting San Francisco
Fabulous Southern California
Cultural Palo Alto

companies pay interview, relocation and agency expenses

submit resume in confidence to:

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Palo Alto, Calif.

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 129A)

The full benefits of transistorizing mobile equipment can now be realized. For the Harp Cathode warms up in so short a time that one can transmit instantly from a cold start, eliminating the need for standby currents which, beside creating power supply problems, generate heat, adversely affecting temperature-sensitive semiconductors and degrading equipment performance.

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The Harp Cathode is inherently rugged and readily passes a life test of over 30,000 switches.

The Harp Cathode has already been incorporated into the type 8042, a fast warmup version of the type 6146 with the same electrical characteristics. The 8042 (25 watt dissipation; 175 Mc; ICAS) is immediately available in pre-production quantities. In the near future, a full line of Harp Cathode twin tetrodes will become available.

Further information may be obtained by writing to the firm.

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A new, 8-page brochure bearing the title of "The Technique of Fully Automatic Coil Winding" is being made available by **Industrial Winding Machinery Corp.,** P.O. Box 744, Church St. Station, New York 8, N. Y. This pamphlet describes the operation of Aumann Model WPA coil winding machine which can be equipped for semi- or fully-automatic winding of field coils, bobbins, voice coils, armatures, and so forth. This heavy duty floor model also can be furnished with dual winding heads for primary and secondary windings. The brochure also illustrates and describes the operation of a refinement of Model WPA, a fully automatic machine which inserts the bobbin, starts the wire, winds the coil, cuts the wire and seals the winding, and then ejects the wound coil. A copy of this brochure can be secured by writing to the firm.

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SENIOR DEVELOPMENT PHYSICISTS

Advanced degree in Physics or E.E. preferred. Must be familiar with latest techniques in the design of advanced HF receivers and transmitters and possess working knowledge of modern HF networks employing ferrites and metallic tape cores. Strong theoretical background in modern linear circuit theory desired. Will carry out laboratory development and implementation of new HF communications systems.

SENIOR ELECTRONIC ENGINEERS

Advanced degree in E.E. preferred. Must be familiar with conventional pulse circuit designs and applications. Technical background should include substantial experience in circuit and data recovery systems using both analog and digital techniques. Knowledge of principles and application of modern information theory including correlation techniques helpful. Will be responsible for the design of sub-systems.

JUNIOR ELECTRONIC ENGINEERS

To assist Senior Engineers and Scientists in the development of HF communications and data process equipment. Should have formal electronics schooling and 2 years' experience in circuit design checkout or analysis of HF communications, Radar Pulse, Analog/Digital or Data Recovery equipment. Construction of prototypes of new and interesting equipment and design of individual components of communications and data processing systems will comprise the major efforts of selected applicants.

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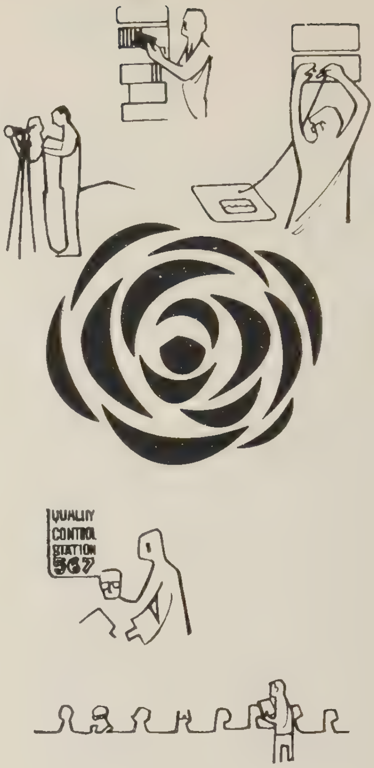

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ELECTRICAL ENGINEERS: data processing, radar, missiles, communications.
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Section Meetings

AKRON

"Important Areas of Electronic Research," H. F. Lanier, Res. & Engrg. Dept. USA. Joint meeting with Cleveland Section. 4/18/61.

"Inertial Navigation & New Developments in Inertial Components," Bernard Lichenstein, GPI; Election of Officers. 5/16/61.

ALAMOGORDO-HOLLOMAN

"Traveling Wave Tubes," Kenneth Suggs Sperry Gyroscope Co. 5/23/61.

ALBUQUERQUE-LOS ALAMOS

"History of New Mexico Territory," Sheldon Dike, Dikewood Corp.; Fellow Award Presentation to Sheldon Dike. 3/14/61.

"Selected Engineering-Physics Problems of a High-Current Multiple Rhumbatron Electron Accelerator," T. J. Boyd, Jr., and Douglas Venable, Los Alamos Scientific Lab. 4/22/61.

Election of Officers. 5/19/61.

Annual Picnic. 6/10/61.

ATLANTA

"FM Stereo Multiplex Systems," R. A. Holbrook, WSB, WSB-TV. 5/26/61.

BAY OF QUINTE

Annual Meeting—Film "Gateways to the Mind." 6/7/61.

BEAUMONT-PORT ARTHUR

"What's Wrong With Everybody," M. I. Summerlin, Texaco. 5/23/61.

BENELUX

"Microwaves in the Study of Physical Phenomena," J. Volger, C. W. van Es, and F. C. de Ronde, Philips Res. Lab. 5/26/61.

"Aspects of Automation in Oil & Chemical Industries," A. B. Mijnheer, Shell Nederland Raffinaderij; "New Developments in Process Control," A. C. Timmers, Shell Nederland Raffinaderij; "Applications of Electronic Punch Card Systems for Material Administration," D. J. Termeer, Shell Nederland Raffinaderij. 6/12/61.

BINGHAMTON

"Status & Future of Teaching Machines," John Forman, IBM. 6/7/61.

BOSTON

"Missile Gap—Fact or Fancy," M. V. Shilling, Raytheon Co. 3/12/61.

"Ballistic Missile Early Warning System," D. B. Holmes, RCA; Election of Officers. 5/17/61.

BUFFALO-NIAGARA

First Annual Spring Dinner-Dance. 4/14/61.

"Electronics in Industrial Control," D. L. Pierce, Westinghouse Elec. Corp.; Election of Officers. 5/17/61.

CEDAR RAPIDS

"Airborne Communications Subsystem Integration," E. A. Habeger, Collins Radio Co.; "A Method for Reduction of Semiconductor Rectifier Noise," A. E. Glandon, Collins Radio Co.; "Equipment Simulators for Electronics System Testing," A. H. Wulfsberg, Collins Radio Co.; "Navigation Display for Advanced Aircraft," D. C. Sather and G. M. Stockwell, Collins Radio Co. 5/17/61.

CENTRAL FLORIDA

"Commercial Satellite Systems," Dr. Upthegrove, Bell Tele. Labs. 4/28/61.

(Continued on page 134A)

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Technical University
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Section Meetings

(Continued from page 133A)

CINCINNATI

Student Papers Presentation. 5/16/61.

CLEVELAND

"Electronic Techniques in Medicine," Saul Gilford, Gilford Instruments; Film—"Toshiba in Progress." 5/11/61.

COLOMBIA

"Computer Systems—Their Application to Management," E. Rugales and E. Nieto, IBM. 5/12/61.

CONNECTICUT

"Discrete Data Control Systems," D. P. Lindorff, Univ. of Conn. 2/16/61.

"Fundamental Properties of Magnetic Materials," R. M. Bozorth, Bell Tele. Labs. 2/23/61.

"Microwave Uses of Magnetic Materials," Peter Tannenwald, Lincoln Labs. 3/2/61.

"Application Survey of Magnetic Materials," H. F. Storm, GE Co. 3/9/61.

"Magnetic Amplifiers," R. C. Barker, Yale Univ. 3/16/61.

"Magnetic Logic," Umberto Gianola, Bell Tele. Labs. 3/30/61.

"Magnetic Memories," Jan Rajchman, RCA Labs. 4/6/61.

"Magnetohydrodynamic Power Generation AC or DC," E. C. Lary, United Aircraft Corp. 4/27/61.

"Certain Aspects of Color Television," Peter Goldmark, CBS Labs. 5/25/61.

DALLAS

Installation of Officers. 5/25/61.

DENVER

"Why the Hewlett-Packard Company Moved to Loveland, Colorado," Stan Selby, Hewlett-Packard Instrument Co.; Election of Officers. 5/18/61.

DETROIT

"Present HOPE in Indonesia," James Vinall, WJR; Election of Officers. 5/26/61.

EL PASO

Tour of KTSM-TV. 5/25/61.

ERIE

"Survey of DC Measuring Devices," Julius Praglin, Keithley Instrument Corp. 5/17/61.

FLORIDA WEST COAST

"Improved Air Traffic Control System," A. C. Packard, USN. 5/17/61.

FORT HUACHUCA

Election of Officers—PGMIL Chapter. 5/18/61.

"Integrated Electronics," E. G. Witting, Deputy Asst. Secy. of Army for R&D. 5/22/61.

HAWAII

"Moon Bounce Communication: History & Development," W. W. Broome, USN; "Moon Bounce Communication: Technical Discussion," C. T. Palmgren, USN. 5/10/61.

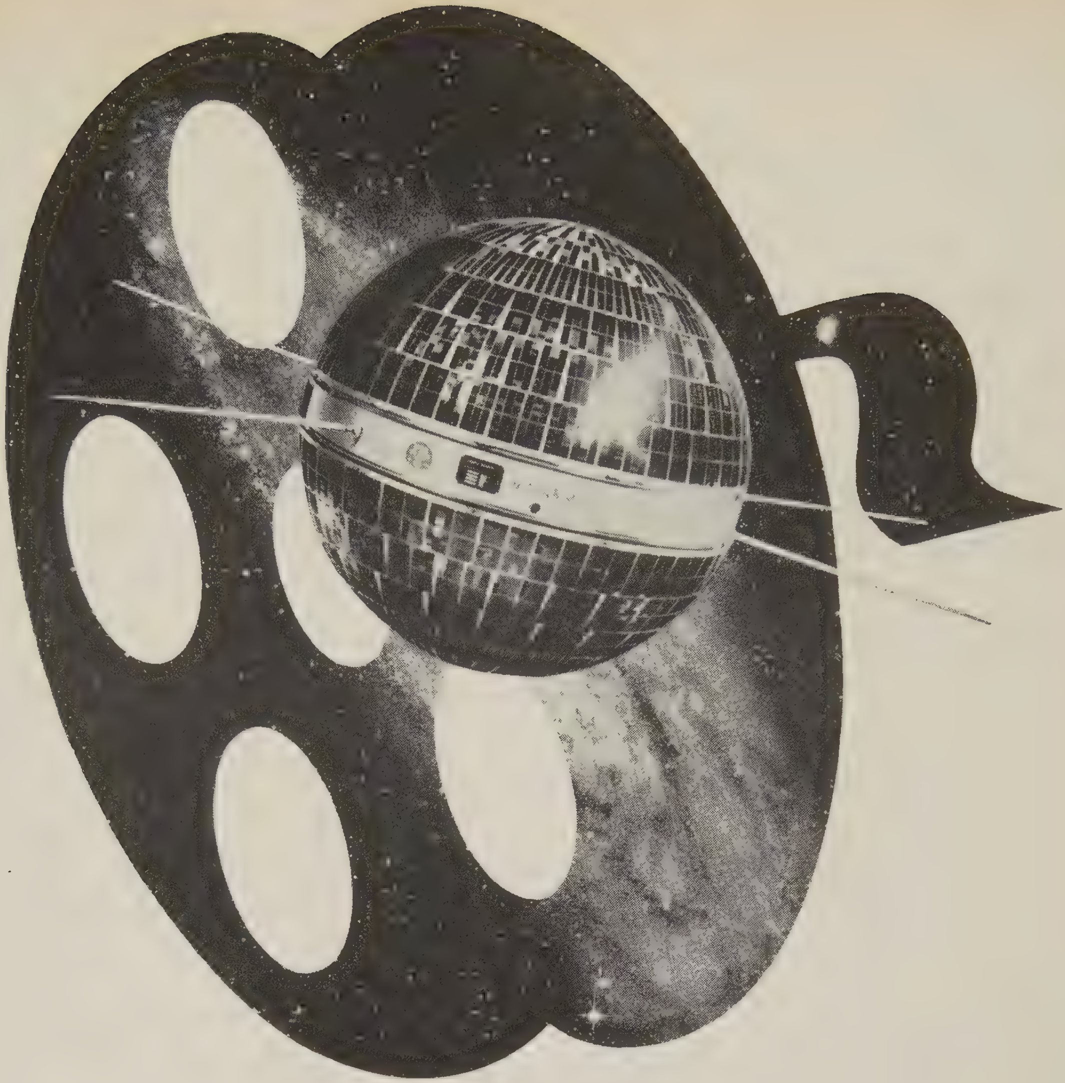
HUNTSVILLE

"Recent Advances in Electro-Optical System Technology," E. L. Crosby, Jr., Electromechanical Res. Co. 3/30/61.

"Inertial Guidance Control Concepts," W. V. Gudaitis, ABMA. 4/27/61.

"State of the Art in Electron Tubes," P. J. Erdle, Sylvania. 5/25/61.

(Continued on page 136A)



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- Support equipment systems design
- Control systems analysis
- Electromechanical design
- Space communications systems
- Telemetry systems design
- Antenna systems
- R-F transistor equipment design
- Transistor circuit design
- Guidance systems analysis
- Materials and processes
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Those attending WESCON are invited to visit STL at Booth Number 209

Section Meetings

(*Continued from page 134A*)

INDIANAPOLIS

Tour of Sarkes Tarzian Tuner Plant. 5/19/61.

"Astronomy from Satellites," R. M. Nidey, Kitt Peak Nat'l Observatory, Ariz. 6/8/61.

KANSAS CITY

Annual Family Picnic. 5/28/61.

LUBBOCK

"Voices Across Time & Space," Glenn Scott, Southwestern Bell Tele. Co. 5/23/61.

MILWAUKEE

"Relativity, Atomic Clock & Satellites," Harold Lyons, Electro-Optical Systems, Inc. 4/19/61.

"Construction & Application of Silicon Rectifiers," R. S. Rudesill, E. A. Dymacek, RCA. 5/9/61.

Annual Student Night. 5/18/61.

NORTHERN NEW JERSEY

"PCM Transmission Systems," E. E. Sumner, Bell Tele. Labs. 5/10/61.

OKLAHOMA CITY

"Echo-I," George Gibson, George Holt, Southwestern Bell Tele. Co.; Election of Officers. 5/8/61.

ORLANDO

"Molecular Electronics," S. M. Skinner, Westinghouse Elec. Co. 4/19/61.

"Improved Demodulation & Predetection Recording Technique," L. L. Rauch, Univ. of Mich. 5/10/61.

PHILADELPHIA

"Your Husband is an Engineer," R. B. Chapman, III, Aircraft Armaments, Inc. 5/3/61.

QUEBEC

"The Prediction of Radio Propagation," P. DuBerger, Can. Arm. Res. & Dev. Est. 6/9/61.

ROME-UTICA

"Flexible Disk Storage Devices," R. T. Pearson, Lab. for Electronics; "A Thin Film Multi-Bit Storage Device," Harvey Rubinstein, Lab. for Electronics. 3/28/61.

"Molecular Electronics," Eugene Strull, Westinghouse Corp., 4/18/61.

8th Annual Mohawk Valley Management Seminar—"Management—Force or Persuasion," 4/25/61.

"Rocket Telemetry," Fred Fitch, Frank Van Horn, Rome Free Academy; "Hypothermia," Raymond Kempf, New Hartford Central School, Joint Armed Forces Communications & Electronics Association Meeting. 5/23/61.

SACRAMENTO

"Radio Astronomy," Mrs. Natalie Leonard, Sacramento State College; Election of Officers. 5/18/61.

SALT LAKE CITY

Student Paper Contest. 5/11/61.

SAN DIEGO

Tour of Kin Tel & Cubic Corp. Joint meeting with AIEE. 5/3/61.

"Phase Lock Receiving Systems," P. A. Hicks, Smyth Res. Assocs. 6/7/61.

SHREVEPORT

"Application of Transistors & Tunnel Diodes to Amateur Radio Service," W. E. Owens, La. State Univ. 6/6/61.

(*Continued on page 138A*)

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All qualified applicants considered without regard to race, creed, color or national origin.

Section Meetings

(Continued from page 136A)

SOUTH BEND-MISHAWAKA

Tour of Indiana Steel Products Plant. 5/23/61.

SOUTHERN ALBERTA

"Supervisory Equipment for Use Over Mobile Communications Facilities," Art Davis, Wes Johnston, Calgary Power Ltd. 1/17/61.

"A Variable Capacitance Parametric Amplifier," W. C. Benger, Northern Elec. Co. Ltd. 2/21/61.

Student Papers Award. 3/22/61.

"Antennae & Transmission Lines for Light Route Radio System," R. P. Matthews, Andrew Antenna Corp. 4/19/61.

TUCSON

"Some Recent Advances in Microwave Power Tubes," C. W. Carnahan, Regional Director of Region 7. 5/2/61.

TULSA

"Basic Theory & Fundamental Circuit Application of Tunnel Diodes," Lee Bennett, Continental Oil Co. 2/16/61.

Presentation of Student Papers. Joint meeting with AIEE. 2/28/61.

"An Electronic Multichannel Analog Correlator," G. L. Brown, Continental Oil Co. 4/20/61.

Annual Banquet. 5/16/61.

VIRGINIA

Student Papers Award. 5/12/61.

Talk & Demonstration on "Optical Masers," W. L. Bond, Bell Tele. Labs. 5/19/61.

"The Engineering & Management of a Major Defense System—BMEWS," H. W. Phillips, RCA. 6/9/61.

WICHITA

"Magnetic Amplifiers," H. B. Hamilton, Univ. of Wichita. Joint meeting with AIEE. 3/1/61.

"Space Communications," J. L. Glaser. Bell Tele. Lab. Joint meeting with AIEE. 3/14/61.

"Linear Modulation Systems," Nick Damaskos, The Boeing Co. 4/3/61.

"The Ampex Video Recorder," Mr. Barnhill, KTVH. 5/17/61.

"Transmission & Boresight Problems in Radome Design," Bill Cooper, Boeing Co.; Election of Officers. 6/10/61.

SUBSECTIONS

EASTERN NORTH CAROLINA

"Diode Manufacture," Walter Dimmick, ITT Kellogg. 4/14/61.

LANCASTER

"Cryogenics & its Application to Electron Devices," Hans Meissner, Stevens Inst. of Technology. 4/25/61.

"Electronic Aids to Speech Analysis," F. A. Hofman, Lancaster Cleft Palate Clinic; Election of Officers. 5/23/61.

NASHVILLE

"Pushbutton Pipelining," W. E. Marquis, Columbia Gulf Transmission Co. 6/13/61.

NEW HAMPSHIRE

"Problems of Space," P. J. Melucas, Hanscom Field; Election of Officers. 6/7/61.

ORANGE BELT

"New RF Solar Disturbances & Related Phenomena," Lewis Larmore, Lockheed Aircraft Corp. 6/6/61.

PASADENA

"Space Communications at Optical Wavelengths Using Sunlight," D. D. Erway, Electro-Optical Systems, Inc. 5/17/61.

(Continued on page 140A)

New Positions at

SYLVANIA

RESEARCH & DEVELOPMENT LABORATORIES

on the San Francisco Peninsula

The Reconnaisance Systems Laboratory and Electronics Defense Laboratories are expanding their R&D facilities and advancing the state of the art—as well as America's defense capabilities—at Sylvania Mountain View Operations. Here, in the heart of the San Francisco Peninsula, numerous new electronics research and development programs are under way. Challenging positions for electronic engineers exist at all levels. Positions include:

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B. S. or M. S. degree and U. S. citizenship required; Ph. D. required for some positions. For further information, please contact Mr. R. R. Keeffe at Box 188, Mountain View, Calif.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

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Government Systems Management
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WHAT WE DO FOR YOU—

Take all the work from you—no need for you to write to five or six companies, fill out applications for each one, only to find there is no job that interests you. We do all that for you, find the job that you want—in the location you want—we work with over 250 companies—all over the country.

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Send us 3 complete resumes, telling us your present and desired salary; the kind of work you want and where you would like to live. That is all you have to do!

THEN YOU—

Wait to hear from us or our clients. There is no need to write directly to any companies, as we do all that for you and at absolutely NO COST TO YOU!

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☐ Radar Techniques
☐ Logic Design
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You are cordially invited to visit Electronics Professional Center at WESCON.

Section Meetings

(Continued from page 138A)

READING

"Magneto Hydrodynamics," John Lothrup, Avco. 1/13/61.

"A Semiconductor Magnetron Modulator," F. A. Gateka, Bell Tele. Labs. 2/16/61.

"Creativity," T. T. Shea, Western Elec. Co. 3/16/61.

"Variations in Stereophonic Tape & Disk Pick Ups," O. B. Shockley, G. Barbey Co. 4/20/61.

WESTCHESTER

"Space Vehicle Guidance," James Campbell, GPL. 5/17/61.

"Bionics—Biology or Engineering?" William Van Bergiejk, Bell Tele. Co. 4/19/61.

WESTERN NORTH CAROLINA

"Techniques of Soldering in Electronic Equipment," William Seoggins, Murphy & Cota. 5/26/61.

Membership

The following transfers and admissions have been approved and are now effective:

Transfer to Senior Member

Agusta, B., Poughkeepsie, N. Y.
Aitchison, R. E., Sydney, N.S.W., Australia
Amore, I. C., Bogota, Colombia, S. A.
Behymer, D. E., Danville, Ind.
Bergseth, F. R., Seattle, Wash.
Berkley, C., Great Notch, N. J.
Bernaert, A. L. J., Brussels, Belgium
Bluhm, R. W., Little Falls, N. J.
Chalmers, E. D., Crystal Lake, Ill.
Clement, P. R., Princeton, N. J.
Craig, J. A., Moorestown, N. J.
Cruz, J. B., Jr., Urbana, Ill.
Eckles, W. W., Jr., Beaumont, Tex.
Curtis, E. I., Palo Alto, Calif.
Denison, J. W., Largo, Fla.
Dorey, J. D., Montreal, P. Q., Canada
Eddy, W. L., Orlando, Fla.
Eliander, H. F., Jr., Tigard, Ore.
Fernandez-Rivas, L. A., St. Davids, Pa.
Fogarty, J. D., Erdenheim, Philadelphia, Pa.
Gedance, A. R., Severna Park, Md.
Gifford, R. P., Lynchburg, Va.
Goldie, H. J., North Vancouver, B. C., Canada
Gregory, T. R., King of Prussia, Pa.
Groginsky, H. L., Wayland, Mass.
Halina, J. W., Paramus, N. J.
Harrington, C. F., Bedford, Mass.
Hecker, H. F., Elberon Park, N. J.
Hetrich, G. R., Baltimore, Md.
Hillman, L., Englewood, N. J.
Horn, R. E., Severna Park, Md.
Houston, D. R., North Linthicum, Md.
Hoyt, W. A., Quincy, Ill.
Ingram, D. B., Redondo Beach, Calif.
Jacob, F. C., Davis, Calif.
Karns, K. B., Kansas City, Mo.
Lattin, W. J., Owensboro, Ky.
Longino, D. R., Jr., Westover A.F.B., Mass.
Malloy, J. H., Silver Spring, Md.
Marlow, H. C., Rome, N. Y.
Masnik, M., Syracuse, N. Y.
McGinley, J. H., State College, Pa.
McAllister, J. C., Kirkwood, Mo.
Metzger, A. C., Verona, N. J.
Moddy, J. M., Cedar Rapids, Iowa
Munk, R., La Jolla, Calif.
Scarfman, H., Lexington, Mass.
Scott, W. G., Orange, Calif.

(Continued on page 142A)

ORI

ENGINEERS • PHYSICISTS

CAREER POSITIONS

POLARIS SYSTEM

ORI is a private corporation owned and directed by scientists and engineers. Continued expansion has created several new and permanent career positions for Engineers and Physicists with substantial experience and project leader potential. The duties relate to coordination of the nation's industrial and r & d organizations working on the Polaris System. Respondents must be able to undertake certain amount of travel.

Inertial Guidance Systems Design

BS in EE or Physics, MA preferred. Several years of direct experience in inertial guidance systems design, either air-borne or shipboard, and servo systems analysis.

Digital Computing

MSEE desirable. Several years of experience with air-borne and/or shipboard digital computer operation. Should know transistor applications, digital to analogue techniques, computer logic, circuitry.

Electro-Mechanics

Position requires an Electro-Mechanical Engineer with inertial platform experience. Should know platform structures, resolvers, torque motors, gyros, accelerometers, and electronic modual techniques. BS or MS.

All qualified applicants will receive consideration for employment without regard to race, creed, color or national origin.

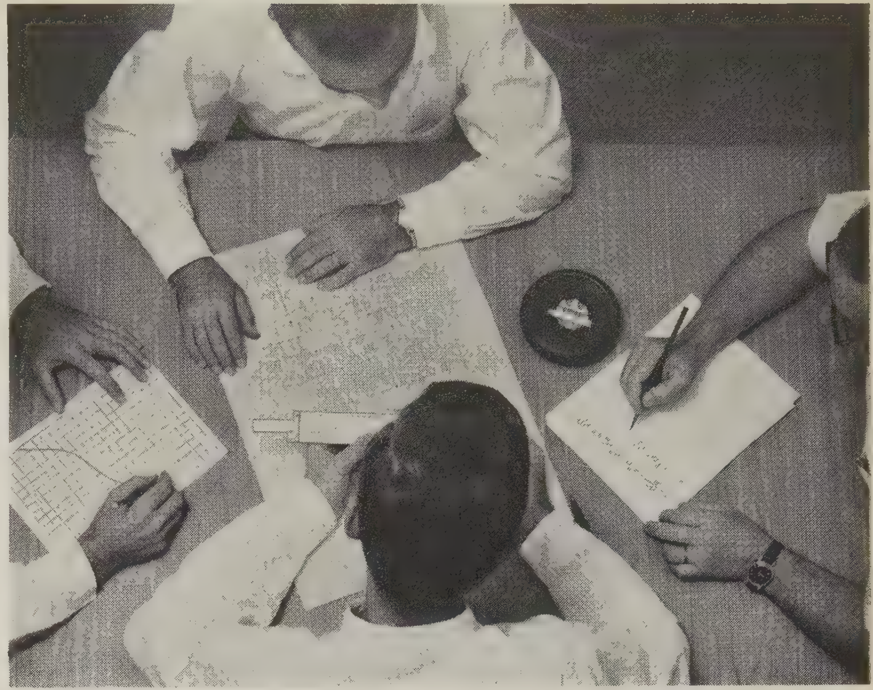
Contact: Dr. Emory Cook,
President and Technical Director

OPERATIONS RESEARCH INCORPORATED

8605 Cameron St., Silver Spring, Md.
(A residential suburb of Washington, D. C.)
JU 8-6180

at MOTOROLA in PHOENIX:

Leadership in action



Project leaders at Motorola are engineers and scientists who have won their right to leadership — with ideas, talent, and dedication — while working on challenging assignments in Project Groups. These teams are carefully selected — to get the optimum combination of experience and capabilities, and to utilize each man's talents to the fullest. Opportunities for individual advancement and career fulfillment are broadened and enhanced by Motorola's widely-diversified activities in advanced military electronics. Leadership in action is a vital force at Motorola. It provides the stimulus for challenging the state-of-the-art in Project Group assignments, assuring engineers and scientists of ever-broadening horizons for tomorrow. And Arizona's world-famed climate and beauty add to the whole family's year-round health and pleasure.

Immediate Opportunities

- Systems Test Equipment Design
- Communications and Navigation
- Systems Analysis and Preliminary Design
- Missile and Space Guidance and Control
- Digital Circuitry Design
- Microwave and Radar
- Reliability and Components
- Solid State Devices

All qualified applicants will receive consideration for employment without regard for race, creed, color, or national origin.

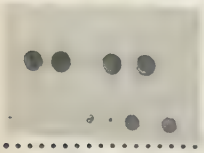
Write Phil Nienstedt (Dept. 801)

MOTOROLA

MILITARY ELECTRONICS DIVISION, WESTERN CENTER
P. O. Box 1417, Scottsdale, Arizona

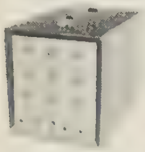
Motorola also offers opportunities at
Chicago, Illinois, and at Culver City and Riverside, California

ACCURATE RESEARCH STARTS WITH
Rutherford
PULSE INSTRUMENTATION



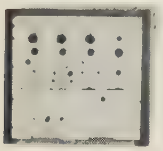
Model B-11 REMOTELY PROGRAMMABLE PULSE GENERATOR

Designed specifically for automated check out systems, this all-purpose Pulse Generator may be programmed to fill a broad range of requirements.



Model B-10 TRANSISTORIZED PORTABLE HIGH-SPEED PULSE GENERATOR

A versatile, general purpose portable unit for field and laboratory use featuring a self-contained, rechargeable battery pack which allows independent operation "in the field" as well as from standard line voltage.

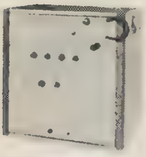


Model B-9 HIGH QUALITY PULSE AND TIME DELAY INSTRUMENTATION

Designed on the modular building block concept and featuring accurate transistorized circuitry in a wide range of specifications. It provides special purpose generators to meet any pulse requirement.

Model B-7B HIGH REPETITION RATE PULSE GENERATOR

High performance and wide versatility—50v into 50 ohms @ 30% duty factor, rep. rate to 2 mc, widths .05 us to 10,000 us, delays to 10,000 us. Rack mountable new single unit construction.



Model B-5A 10 MEGACYCLE PULSE GENERATOR

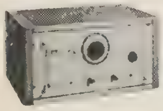
Built to the most exacting standards of precision engineering, offers an unparalleled combination of good clean pulses and high repetition rate with no greater than 8 mus rise and fall time.

Model B5-2 HIGH SPEED 10 MEGACYCLE DOUBLE...PULSE GENERATOR

Producing 2 pulse trains derived from a single oscillator—featuring output pulse adjustable in width from 20 mus to 12.5 us, rise and fall time no greater than 8 mus.

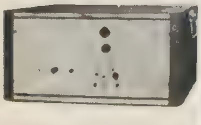
Model B-2A A GENERAL PURPOSE PULSE INSTRUMENT

Produces pulses of accurately controlled widths, amplitude and time delay at low impedance. Internal oscillator gives rep. rates from 10 cycles to 100 kc. Pulse widths from .08 us to 1,000 us.



Model A-2 and Model A-4 TWO TIME DELAY GENERATORS

Feature low jitter, linear scales, small repetition rate effects, external connector provided for delay voltage so that unit may be externally time modulated, easily read dial controls.



Model A9 PULSE AND TIME DELAY SYSTEMS

A highly accurate, jitter free time delay generator featuring time delays from 0.8 to 100,000 usec. Multiple outputs including gates and ramp available at front panel connectors.

See our complete line at the Wescon Show—Booth Nos. 1501 and 1502, or for complete bulletin write to Dept. 8G.

Rutherford ELECTRONICS CO.
8944 Lindblade Street · Culver City, California · TWK-CVR-CY-4133
pulse generators / pulse systems accurate time delay generators

Membership

(Continued from page 140A)

Spencer, P. F., San Jose, Calif.
Surber, W. H., Jr., Princeton, N. J.
Watson, J. K., Norman, Okla.
Wheatley, W. A., Ann Arbor, Mich.
Willey, R. E., Baltimore, Md.
Williams, R. L., Baltimore, Md.
Witthun, H. D., Nashua, N. H.
Wolff, E. A., Adelphi, Md.
Woodward, A. E., Farmingdale, N. Y.
Yeh, L. P., Washington, D. C.
Youtcheff, J. S., Berwyn, Pa.
Zoller, C. J., Whittier, Calif.

Admission to Senior Member

Armington, R. E., University Park, Pa.
Baccari, C. P., Woodstock, N. Y.
Blum, M. P., Pleasantville, N. Y.
Chase, J. B. E., Huntsville, Ala.
Cohn, N., Jenkintown, Pa.
de Seversky, A. P., New York, N. Y.
Di Frank, J., Jr., Arlington, Va.
Duncan, J. R., Canoga Park, Calif.
Epstein, N. N., Atherton, Calif.
Frantz, F. H., Arlington, Tex.
Frater, G. E., Paoli, Pa.
Fthenakis, E., Philadelphia, Pa.
Fulkerson, A. C., El Segundo, Calif.
Giannini-Mochi, E., Milano, Italy
Giannotto, J. M., West Long Branch, N. J.
Halligan, R. F., Chicago, Ill.
Golovin, N. E., Washington, D. C.
Hellert, M. G., Phoenix, Md.
Jackson, R. R., Pittsburgh, Pa.
Jaffe, D., Alexandria, Va.
Longini, R. L., Pittsburgh, Pa.
Macpherson, A. C., Washington, D. C.
Martin, R. T., Dallas, Tex.
Mauksch, G. S., Ossining, N. Y.
Meyer, F. T., New York, N. Y.
Palmans, E. J., Brussels, Belgium
Paski, E. F., Berwyn, Pa.
Pertschuk, D. W., Norwood, Mass.
Pettas, A. S., Amaroussion, Athens, Greece
Sakuraba, I., Sapporo, Hokkaido, Japan
Smith, V. C., Jr., El Cajon, Calif.
Stevens, M., Havertown, Pa.
Stone, D. L., Palos Verdes Estates, Calif.
Weiland, R. L., Nashville, Tenn.
Westphal, W., Bogota, Colombia, S. A.
Wilcox, G., Kalamazoo, Mich.

Transfer to Member

Berge, R. I., Endicott, N. Y.
Chinn, H. R., Randwick, N.S.W., Australia
Cooper, D. K., Poughkeepsie, N. Y.
Csia, J. Z., West Covina, Calif.
De Luca, L. A., Hampton, Va.
Edling, E. A., Cleveland, Ohio
Heimsness, O. D., Pottstown, Pa.
Herkimer, K. W., Santa Ana, Calif.
Holmes, H. R., Toledo, Ohio
Mark, J. T., Lancaster, Pa.
Moore, A. S., Gloucester, Mass.
Prins, D. W. S., Hyattsville, Md.
Ritter, L. M., Patrick A.F.B., Fla.
Sayles, H. L., Clarendon Hills, Ill.
Scoggin, W. G., Jr., Charlotte, N. C.

Admission to Member

Aagard, K. J., Seattle, Wash.
Abajian, H. K., Altadena, Calif.
Adams, H. G., Northridge, Calif.
Adams, P. M., Towson, Md.
Ainsworth, G. L., Palo Alto, Calif.
Allen, R. J., Haddonfield, N. J.
Altenmueller, O. H., San Jose, Calif.
Anderson, W. R., Annandale, Va.
Apple, C., San Francisco, Calif.

(Continued on page 144A)

HIGH PURITY ELEMENTS

SOUTH PLAINFIELD, N. J., Aug. 1 -- ASARCO SCIENTISTS HAVE DEVELOPED ANALYTICAL TECHNIQUES SO SENSITIVE THEY CAN NOW MEASURE SELENIUM IN HIGH PURITY COPPER TO 1 PART PER 100,000,000. MANY ASARCO ELEMENTS ARE SO PURE THAT PRESENT STANDARD METHODS OF ANALYSIS CANNOT ACCURATELY DETERMINE LEVELS OF SPECIFIC IMPURITIES.

ASARCO HIGH PURITY ELEMENTS ANALYSES as of Aug. 1, 1961

Impurities sometimes found at maximum levels in parts per million
(< denotes less than ppm indicated)

Element and Grade		Bi	Cu	Fe	As	Pb	Ag	Tl	Sn	Te	Au	Na	Cl	Cd
ANTIMONY	A-60	<1	<1	<1	<2	<1								
✓ ARSENIC	A-60		<1											
BISMUTH	A-58		2	1		1	2						<1	
CADMIUM	A-60		<1	<1		1								
COPPER	A-58	No Impurities Detectable by Spectrographic Analysis												
GOLD	A-59		<1	<1		<1	1							
INDIUM	A-58		<1			1		<1	1					
LEAD	A-59	<1	<1	<1										
SELENIUM	A-58		<1		<1					1			<1	
SILVER	A-59		<1	<1		<1								
SULFUR	A-58											1	1	
TELLURIUM	A-58		<1	<1										
✓ THALLIUM	A-60		1	1		<1	<1					2	<1	
ZINC	A-59		<1	<1		<1								<1

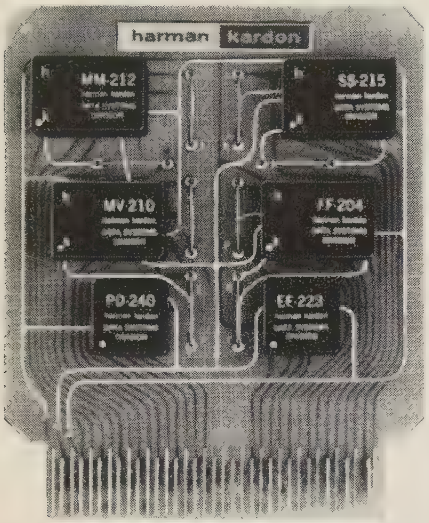
✓ *Denotes element improved since last published analyses.*

ASARCO

The analyses above are among pertinent data compiled by Asarco's Central Research Laboratories in an up-to-date catalogue now available to users of high purity elements. For a copy, write on your company letterhead to American Smelting and Refining Company, 120 Broadway, New York 5, N. Y.

MM-212
SS-215
MV-210
FF-204
PD-240
EF-223

You mix 'em!



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Harman-Kardon's new economical Digital Card Assembly

Now, Harman-Kardon's new flexi-card circuit assemblies bring logical versatility to logical circuits. Each Flexi-card is factory-assembled to your specific requirement quickly, and at competitive prices, for any of the thousands of combinations of digital logic you require.

...And two new series of Encapsulated Logic Modules

Completely compatible modules now available at 125°C. • 5 MC. • 250 KC.

Send for complete details and... FREE guide to Boolean Algebra!

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INCORPORATED • PLAINVIEW, L. I., N. Y.

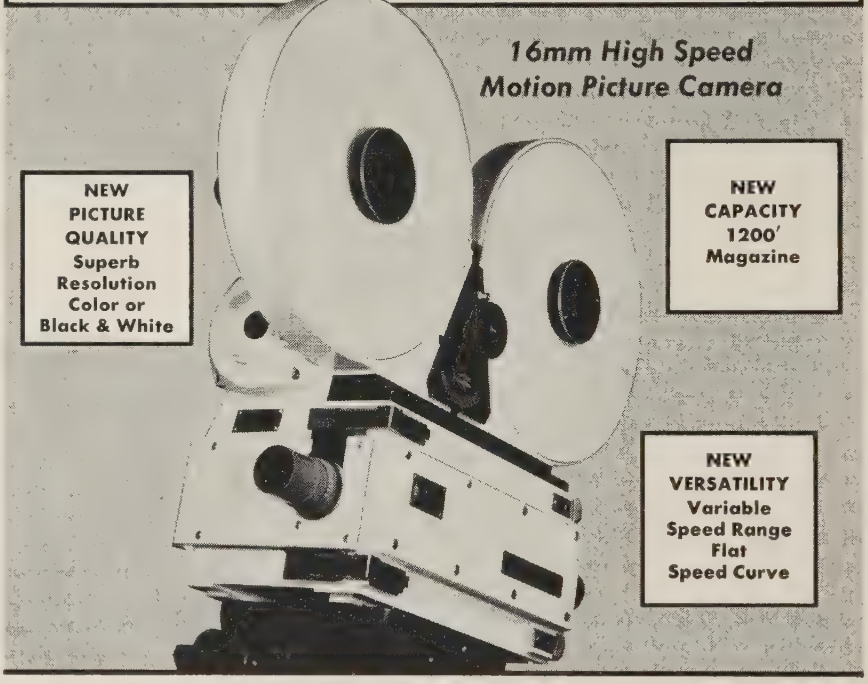
Membership

(Continued from page 142A)

Aronson, R., Detroit, Mich.
Avery, J. P., Indianapolis, Ind.
Avni, Y., Tel-Aviv, Israel
Baber, W. W., Byram Portchester, N. Y.
Bailey, C. C., Upland, Calif.
Bakst, A., Sunnyvale, Calif.
Ball, J. R., Pittsburgh, Pa.
Barr, F. A., Verona, N. J.
Barry, E. D., Palo Alto, Calif.
Bath, E. J., Washington, D. C.
Baughman, R. B., Inglewood, Calif.
Baum, H., East Brunswick, N. J.
Baumann, P. H., Jr., Berkeley, Mo.
Beckett, P. G. S., Detroit, Mich.
Bell, E. F., Jr., Chicago, Ill.
Benedict, J., Boekelo, Netherlands
Bennett, E. M., Bedford, Mass.
Bennett, W. V., Granada Hills, Calif.
Berger, N. W., Palo Alto, Calif.
Berke, H. L., Whitesboro, N. Y.
Beu, D. H., Lexington, Mass.
Black, R. I., Closter, N. J.
Blankenship, M. G., Corning, N. Y.
Blom, S. R., Wayland, Mass.
Bodie, M. W., Dallas, Tex.
Bolinger, W. M., Angwin, Calif.
Boos, R. T., Coopersburg, Pa.
Brick, A., Wantagh, L. I., N. Y.
Caldwell, F. F., Ottawa, Ont., Canada
Carabelas, P. D., Upland, Calif.
Carnell, R. E., Dallas, Tex.
Caulton, M., Princeton, N. J.
Celmer, P. R., Trenton, N. J.

(Continued on page 146A)

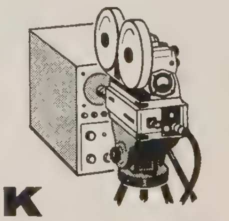
NEW! WF-30 FASTAX


16mm High Speed Motion Picture Camera
NEW PICTURE QUALITY Superb Resolution Color or Black & White
NEW CAPACITY 1200′ Magazine
NEW VERSATILITY Variable Speed Range Flat Speed Curve

Years Ahead in Design and Performance

A high speed camera with large film capacity . . . with a variety of speed ranges and high resolution has long been wanted by industry, the military and the government. The FASTAX WF-30 fills all these requirements and more. Darkroom loaded, "T" core, the magazine holds sufficient film for most studies. Camera versatility is another key feature. Variable speed range, controlled by a solid state loop servo device . . . rapid acceleration with flat speed curve within ±4% selected rate . . . start-stop capabilities. Superb resolution over entire frame results from excellent lens system and a sector shutter between rotating prism and focal plane.

WRITE for complete information and prices on WF-30 . . . the newest FASTAX in the wide line of Wollensak high speed motion picture cameras.



WF-32 OSCILLOGRAPHIC RECORDER

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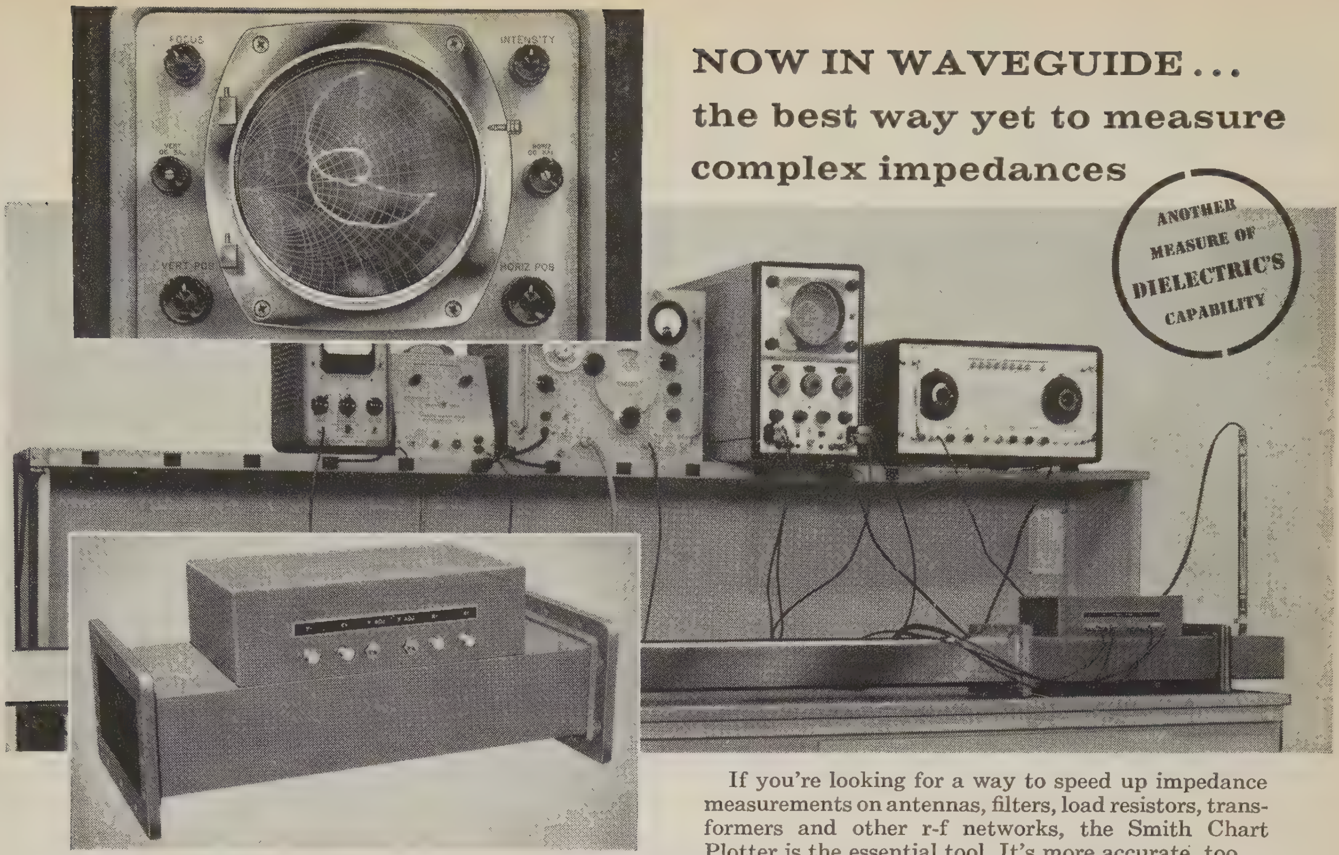
NOW IN WAVEGUIDE . . .

the best way yet to measure complex impedances



Here is the first major breakthrough in the measurement of complex impedance over a band of frequencies. For speed, simplicity, and reliability, it surpasses anything yet used. It's the Smith Chart Plotter, developed by Dielectric Products Engineering Company to obtain instantaneous Smith-Chart display of reflection coefficient as a function of frequency.

Recently 50-ohm coaxial models were announced. *Now these instruments are available in waveguide as well.* Five resolver models span the range 350 to 12000 mc/s. Calibrated mismatch loads are also available.

This unique instrument — along with appropriate auxiliary equipment to form the complete plotter — eliminates the need to tie up highly skilled technical personnel during prolonged test routines that characterize slotted line measurements.

HOW IT WORKS

With Dielectric's Smith Chart Resolver, a swept-signal generator sweeps repetitively over the frequency band desired. The reflection coefficient of the unknown load is resolved into its X and Y components, which are then applied to the X and Y amplifiers of an oscilloscope equipped with a Smith Chart faceplate. A continuous trace of reflection coefficient versus frequency is thus displayed directly. The faceplate can be either a full-scale chart, or one expanded to 1.5:1 VSWR.

As load changes or adjustments are made, impedances change. Simultaneously so does the trace . . . load changes are observed immediately. When a permanent record is required, the oscilloscope trace may be directly photographed. Or, if preferred, an X-Y chart recorder may be used.

If you're looking for a way to speed up impedance measurements on antennas, filters, load resistors, transformers and other r-f networks, the Smith Chart Plotter is the essential tool. It's more accurate, too.

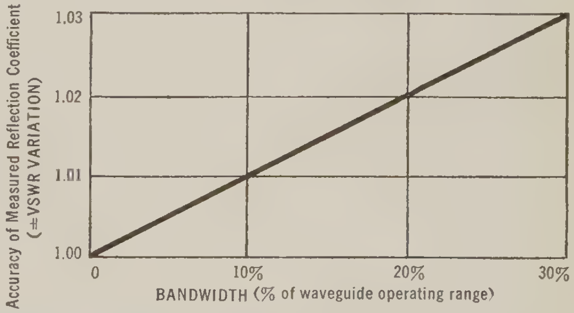
And there is more to come. For the measurement of r-f impedance in systems at any power level to the highest that can be generated, in either waveguide or coaxial line, other forms of the plotter will soon be available to supply a Smith Chart display. These will be particularly useful as system monitors.

SPECIFICATIONS

Nominal impedance............................Z_o (Waveguide)
RF input voltage..................................0.35 volts, rms
Oscilloscope signal voltage . . . 0.2 volts input required for full scale deflection on expanded Smith Chart (1.5 VSWR max) for DC oscilloscope having 1 centimeter/millivolt sensitivity
Accuracy of reflection coefficient measurement ... see graph below
Sweep rate (maximum)..................................60 sps
Spot rotation rate (maximum for full accuracy)...1000 rev/sec
RF input-output terminals ....Optional
Automatic level control terminals.......BNC (where required*)

*ALC information supplied with unit.

For complete description, ask for Bulletin 60-3. You'll get the latest revision and supplement which include both waveguide and coaxial units.



Other areas of **DIELECTRIC** capability in coaxial, waveguide and open wire techniques . . .

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for solutions to
communications
problems.

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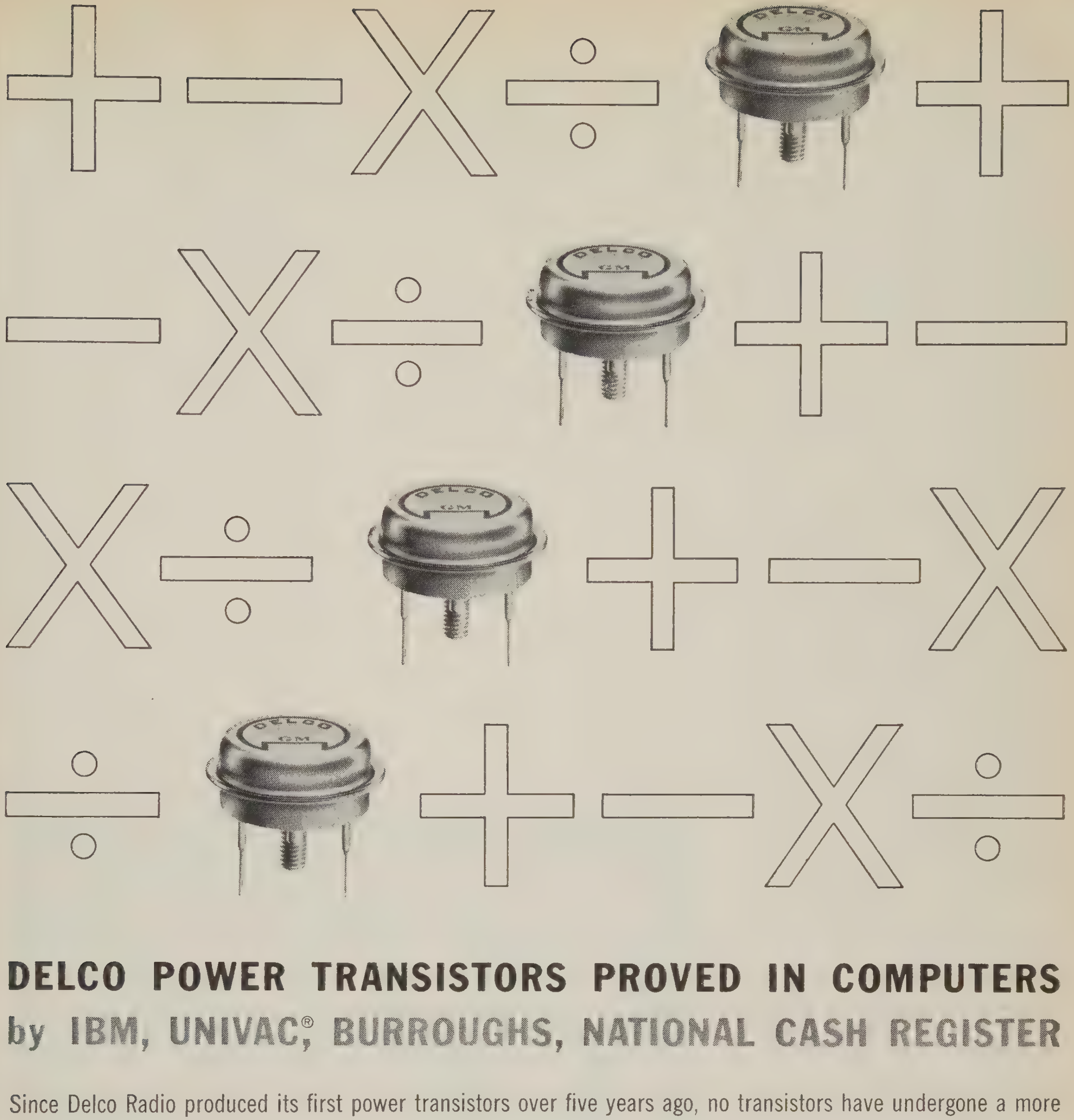

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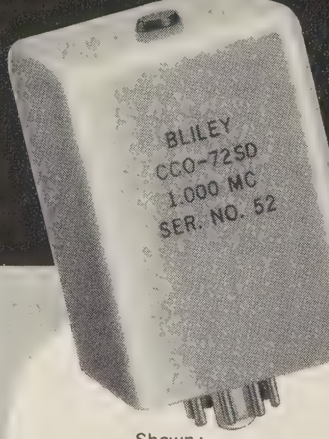
(Continued on page 150A)



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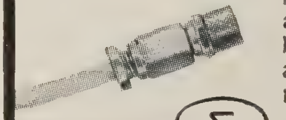

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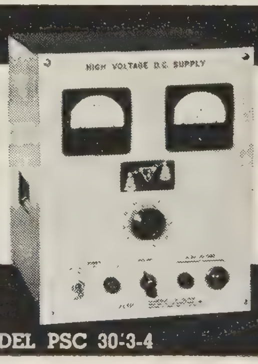

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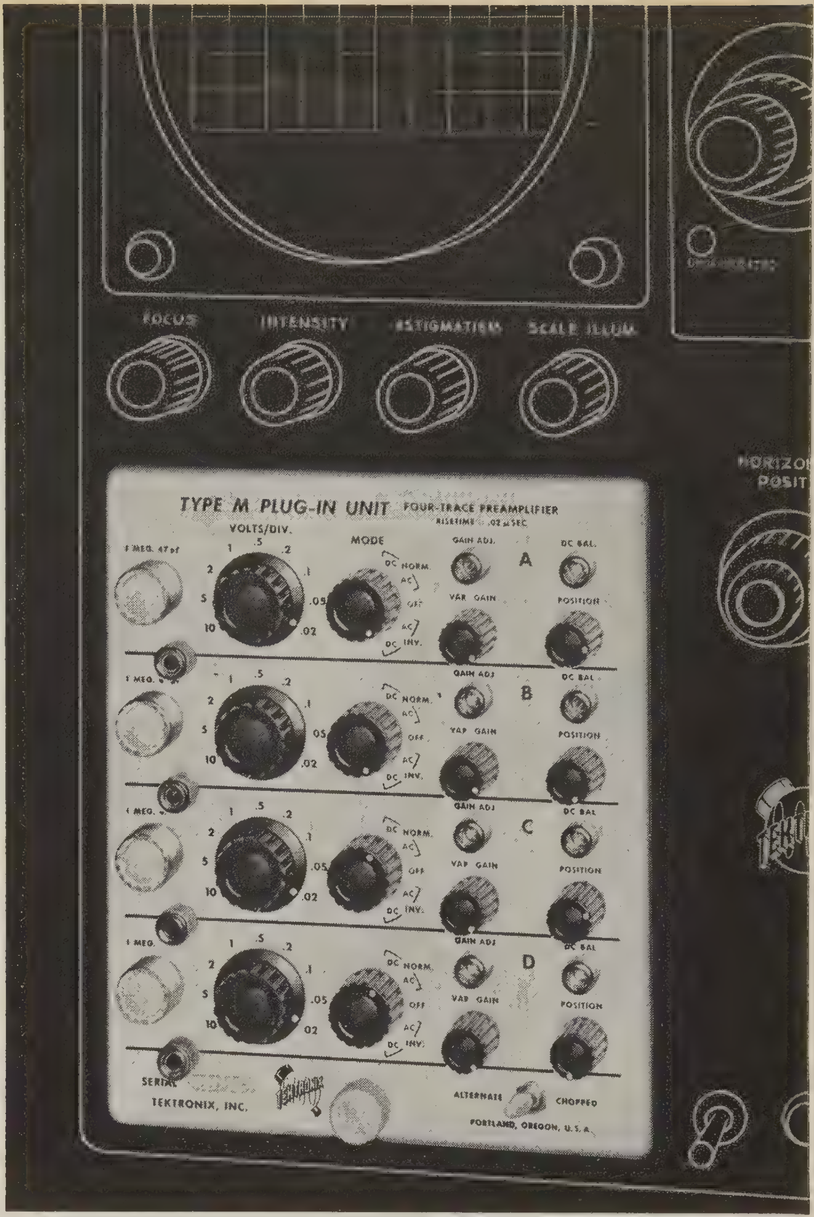

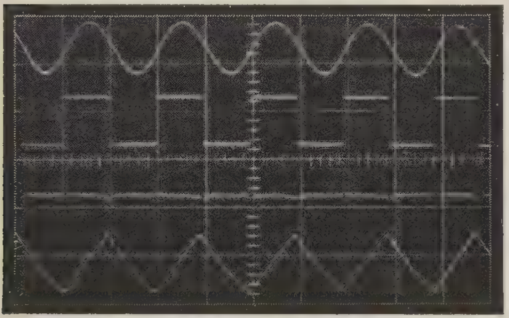

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(Continued from page 150A)

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Advertising Index

IRE News and Radio Notes 14A
IRE People 54A
Industrial Engineering Notes 34A
Meetings with Exhibits 8A
Membership 140A
News—New Products 128A
Positions Open 102A
Positions Wanted by Armed Forces Veterans 108A
Professional Group Meetings 39A
Section Meetings 133A
Table of Contents 1A-2A
WESCON Exhibitors' List 90A

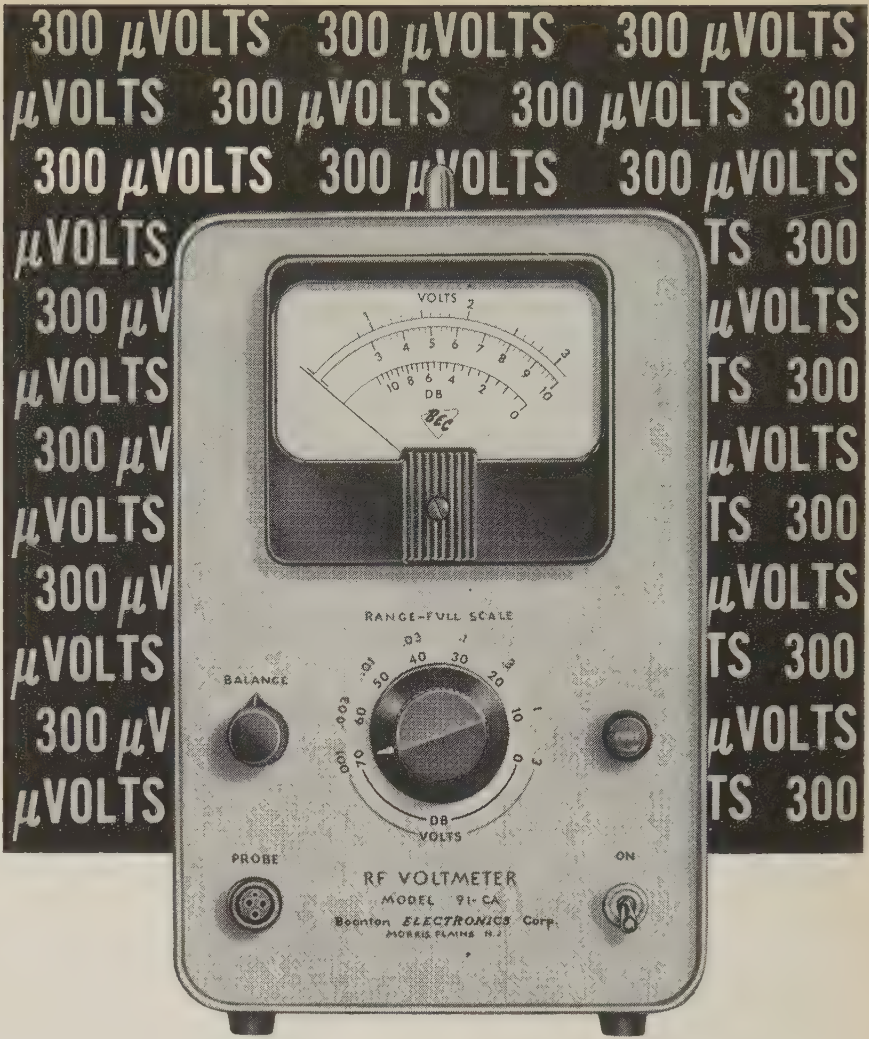
DISPLAY ADVERTISERS

ACF Industries, Inc., ACF Electronics Div. 104A, 131A
A C Spark Plug Div., General Motors Corp. 103A
ATR Electronics, Inc. 70A
Abbott's Employment Specialists 132A
Accredited Personnel Service 140A
Ad-Yu Electronics Lab., Inc. 155A
Airborne Instruments Laboratory, Div. of Cutler-Hammer, Inc. 4A
Airpax Electronics, Inc. 8A
Alden Products Company 54A
American Smelting & Refining Co., Federated Metals Div. 143A
Andrew Corporation 97A
Armed Forces Communications & Electronics Association 66A
Armour Research Foundation of Illinois Institute of Technology 110A
Arnold Engineering Company 91A
Astropower, Inc., Subsid. of Douglas Aircraft Co., Inc. 118A
Autonetics, Div. of North American Aviation, Inc. 27A

Ballantine Laboratories, Inc. 60A
Bell Telephone Laboratories 6A
Binswanger Associates, Charles A. 108A
Bliley Electric Company 148A
Boeing Company 105A-106A
Boonton Electronics Corp. 153A
Brookhaven National Laboratory 130A
Buckbee Mears Company 25A
Bussmann Mfg. Div., McGraw-Edison Company 31A

Canadian Marconi Company 110A
Capehart Corporation 43A
Carborundum Company 35A
Careers, Inc. 126A
Cinch Mfg. Co., Howard B. Jones Div. 51A
Clare & Company, C. P. 10A-11A
Clearprint Paper Company 49A
Cohn Mfg. Co., Inc., Sigmund 40A
Cominco Products, Inc. 98A
Consolidated Reactive Metals, Inc. 85A
Cornell Aeronautical Lab., Inc. 112A, 128A
Corning Glass Works 69A

Del Electronics Corp. 150A
Delco Radio Div., General Motors Corp. 45A, 146A-147A



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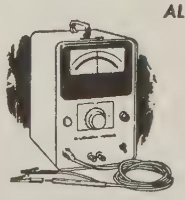
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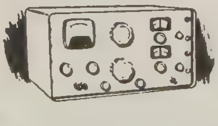
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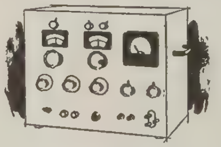
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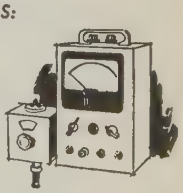
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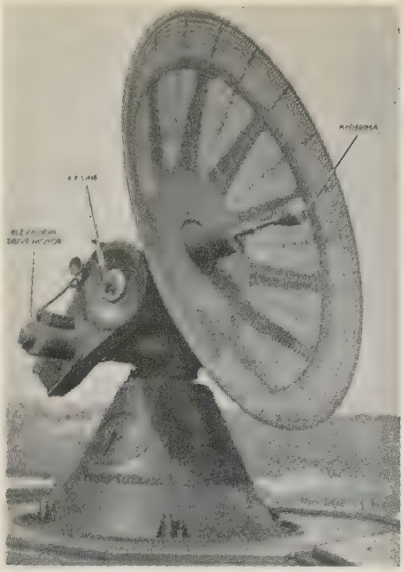

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Advertising Index

DeMornay-Bonardi 58A-59A
Dialight Corporation 81A
Dielectric Products Engineering Co., Inc. 145A
Dikewood Corporation 132A

Eastern Industries, Inc. 62A
Eastman Kodak Company 51A
Eitel-McCullough, Inc. 92A-93A, 149A
Electro-Mechanical Research, Inc. 116A
Electronic Measurements Co., Inc. 99A
Ellis, David 152A
Epsco, Inc. 118A
Ercolino, M. D. 152A

F X R, Div. of Amphenol-Borg Electronics Corp. 78A
Fairchild Semiconductor Corporation 67A
Ferrotec, Inc. 48A
Freed Transformer Co., Inc. 44A

General Electric Company, Defense Systems Dept. 102A
General Electric Company, Missile & Space Vehicle Dept. 121A-124A
General Instrument Company, Capacitor Div. 72A-73A
General Instrument Company, Semiconductor Div. 21A
General Radio Company ....Cover 4
Gorman Machine Corporation 83A

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Advertising Index

Greenberg, Earl 152A
Gudebrod Brothers Silk Company, Inc. 44A
Guilford Personnel Service 137A

Harman-Kardon, Inc. 144A
Heath Company 154A
Hewlett-Packard Company 52A-53A
Hillman, Leon 152A
Himmelstein, S. 152A
Hitachi, Ltd. 80A
Hughes Aircraft Company, Aerospace Engineering Div. 113A
Hughes Aircraft Company, Microwave Tube Div. 13A

Industrial Electronic Engineers, Inc. 100A
Institute of Radio Engineers 38A, 47A
Instrument Society of America 36A
Instruments for Industry, Inc. 110A
International Business Machines Corp. 89A

Jet Propulsion Lab., California Institute of Technology 117A
Johns Hopkins University, Applied Physics Laboratory 108A, 137A
Jones Electronics Co., Inc., M. C. 68A

Kahn, Leonard R. 152A
Kay Electric Company 9A
Keithley Instruments, Inc. 148A
Kepco, Inc. 39A
Kin Tel, Div. of Cohu Electronics, Inc. 34A
Kollsman Instrument Corp. 138A
Kulka Electric Corporation 40A

Lambda Electronics Corporation 75A
Lapp Insulator Company, Inc. 95A
Lenkurt Electric Company, Inc. 132A
Lesser, John 152A
Litton Industries, Inc., Electron Tube Div. 61A
Lockheed Aircraft Corp., California Div. 119A
Lyons, Leonard J. 152A

Magnetic Metals Company 33A
Marconi Instruments 64A
Massachusetts Institute of Technology, Instrumentation Lab. 114A
Massachusetts Institute of Technology, Lincoln Lab. 130A
Mayberry, Len 152A
McCoy Electronics Company 82A
McLean Engineering Laboratories 74A
Measurements, A McGraw-Edison Div. 156A
Micon Electronics, Inc. 150A
Microwave Associates, Inc. 65A
Millen Mfg. Co., Inc., James 64A
Minneapolis-Honeywell Regulator Co., Aeronautical Div. 109A
Minnesota Mining & Mfg. Co., Mincom Div. 79A
Mitre Corporation 120A
Motorola, Inc., Military Electronics Div. 141A
Motorola Semiconductor Products, Inc., Subsidiary of Motorola, Inc. 86A

National Tel-Tronics Corporation 150A
Nexon, V. J. 152A
Nippon Electric Company, Ltd. 84A
Northeastern Engineering, Inc. 12A

Offner Electronics, Inc. 94A
Operations Research, Inc. 141A

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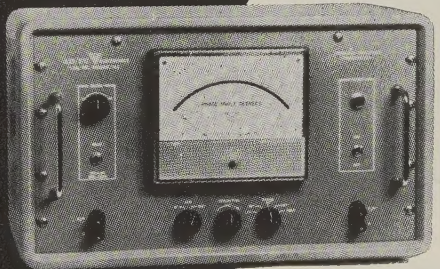

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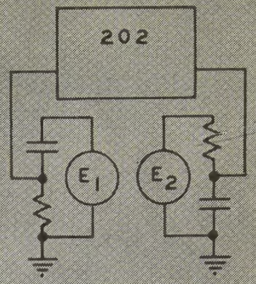

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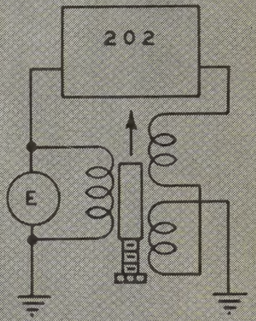

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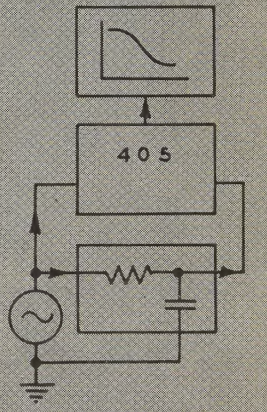

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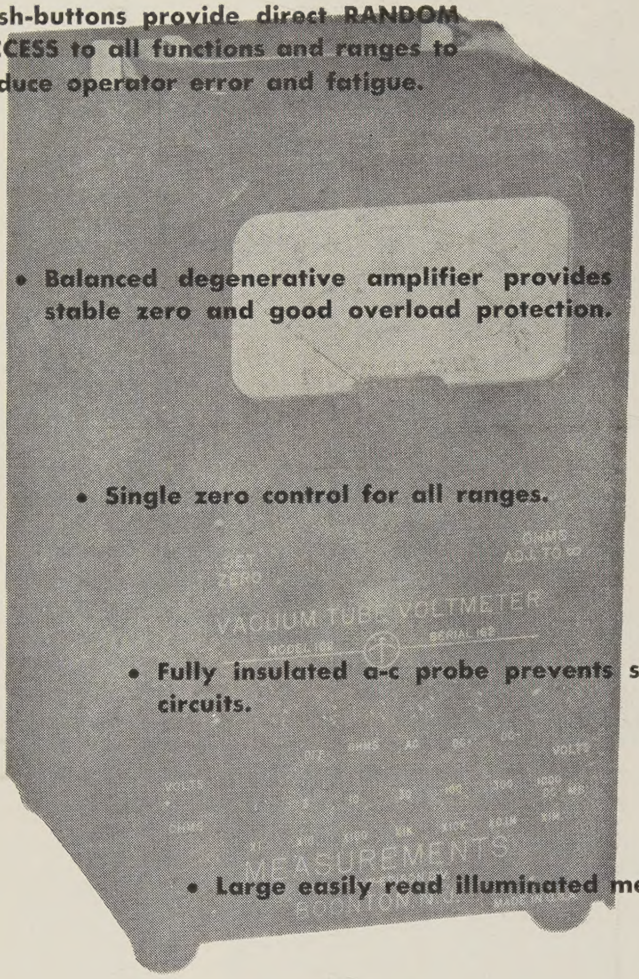

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Advertising Index

Ordnance Research Laboratory, Pennsylvania State University 136A
Ostlund, E. M. 152A

Packard Bell Electronics 71A
Page Communications Engineers, Inc. 81A, 83A, 85A
Panoramic Electronics, Inc. 57A
Parke, Nathan Grier 152A
Permanent Employment Agency 130A
Philbrick Researches, Inc., George A. 50A
Philco Corp., Lansdale Div. ....Cover 3
Philco Corp., Western Development Labs. 135A
Power Designs, Inc. 100A
Price Electric Corporation 56A
Prodelin, Inc. 76A

Q-max Corporation 46A

Radio Corporation of America, Electron Tube Div. 88A
Radio Research Instrument Co. 154A
Ramo-Wooldridge Corporation 115A
Raytheon Company, Microwave & Power Tube Div. 87A
Republic Aviation Corp. 125A
Rixon Electronics, Inc. 46A
Rosenberg, Paul 152A
Rosenthal, Myron M. 152A
Rutherford Electronics Company 142A

Sanborn Company 63A
Sanders Associates, Inc. 128A
Sarkes Tarzian, Inc., Semiconductor Div. 37A
Scientific-Atlanta, Inc. 19A
Security Devices Laboratory 100A
Sensitive Research Instrument Corp. 7A
Sloan, Gardner H. 152A
Space Technology Labs., Inc. 136A
Sprague Electric Company 3A, 5A, 55A, 96A
Stewart Engineering Company 46A
Stoddart Aircraft Radio Company, Inc. 101A
Sylvania Electric Products Inc., Amherst Laboratories 111A
Sylvania Electric Products Inc., Electronic Systems Div. 139A
Sylvania Electric Products Inc., Electronic Tubes Div. 77A

Technical Appliance Corporation 42A
Technical Materiel Corporation 62A
Technical University of Denmark 134A
Tektronix, Inc. 151A
Temperature Engineering Corp. 70A
Texas Instruments Incorporated, Apparatus Div. 29A

United Aircraft Corp., Research Labs. 107A
United Aircraft Corp., Weather System Center 127A
U. S. Navy, Naval Ordnance Laboratory 134A
United Transformer Corp. ....Cover 2

Varian Associates, Tube Div. 17A
Vitro Electronics Div., Vitro Corp. of America .133A

Western Electric Company, Inc. 41A
Western Gold & Platinum Company 98A
Westinghouse Electric Corp., Baltimore Div. 129A
Westrex Co., Div. of Litton Systems, Inc. 23A
Wheeler, Harold A. 152A
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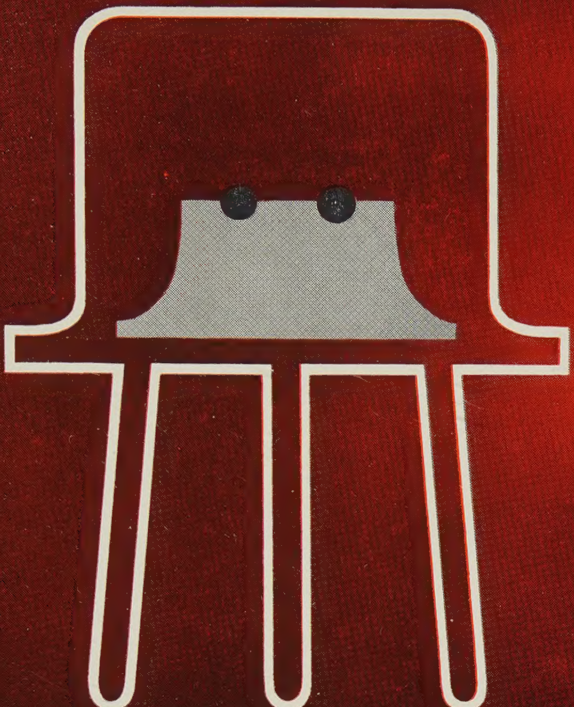
PHILCO EPITAXIAL SILICON MESA



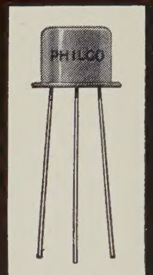
FIRST TO COMBINE

120 V (BV_{CBO})

0.5 V(*SAT*)

150 mc. f_T

2N2087 NPN
CORE DRIVER
LINE DRIVER



TO-5

ABSOLUTE MAXIMUM RATINGS

Storage Temperature ....—65 to +300°C.
BV_{CER} (R≦10Ω)........................80 volts
BV_{CBO}...............................120 volts
BV_{EBO}...................................5 volts
Collector Current I_C....................500 ma
Total Device Dissipation (case 25°C.)....2 watts
Total Device Dissipation (case 100°C.)...1 watt
Total Device Dissipation (free air 25°C.).0.6 watt

ELECTRICAL CHARACTERISTICS (@ 25°C.)

Characteristics	Conditions	Min.	Max.	
h_{FE}	V_{CE} = 1V. I_C = 150 ma.	40	120	
V_{BE}	I_C = 150 ma. I_B = 15 ma.		1.2	volts
V_{CE}(SAT)	I_C = 150 ma. I_B = 15 ma.		0.5	volts
f_T	I_C = 50 ma. V_{CE} = 10V.	150		mc
C_{ob}	V_{CB} = 10V. I_E = 0 ma.		12	pf
I_{CBO}	V_C = 60V. T = 25°C.		2	μa
I_{CBO}	V_C = 60V. T = 150°C.		200	μa
BV_{CER}	R ≦10Ω I_C = 20 ma. pulsed	80		volts
t_r			85	nsec
t_s			100	nsec
t_f			55	nsec

You would expect Philco, as inventor of industry's most capable germanium logic transistor—the MADT, to design Silicon memory components with extra capability, too. And Philco has done it. The 2N2087, forerunner of a broad line of Philco epitaxial silicon mesa transistors, offers an incomparable combination of parameters that may well be the special design solution you require: maximum BV_{CBO} of 120 V., minimum h_{FE} of 40 at $1V_{CE}$, maximum V_{CE} (SAT) of 0.5 V., minimum f_T of 150 mc., maximum C_{ob} of 12 pf., and maximum t_s of 100 nanoseconds.

The new Philco 2N2087 epitaxial silicon mesa delivers optimum drive for computer memory planes, serves as a medium power switch in airborne controls systems, and is ideally suited to a wide variety of other applications such as small power supplies, servo amplifiers, and automation controls. For complete information, write Dept. IRE861.

Immediately available in quantities 1-999 from your Philco Industrial Semiconductor Distributor.

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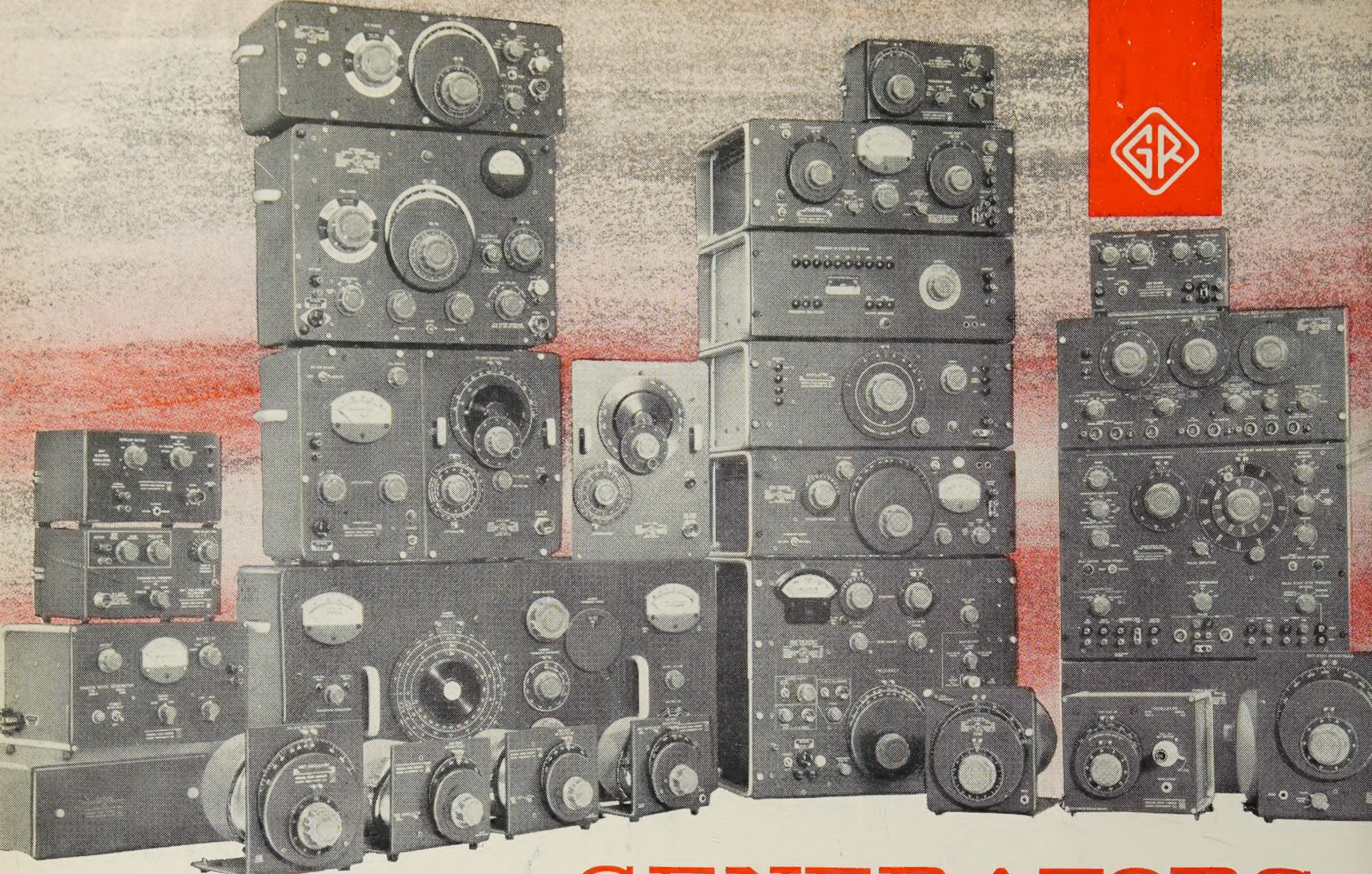

GENERATORS

LOW FREQUENCY, AUDIO, RF, SWEEP

0.01-1000c 3-phase, 4-phase, and variable-phase outputs for servo and feed-back circuit measurements. 1305-A, $940.

20c-500 kc three generators in one; high- and low-impedance sine-wave outputs, and square-wave output. 1210-C, $180*.

20-15000c in 27 fixed-frequency steps; additional coverage from 2-15c with optional extension unit. Very low harmonic distortion, less than 0.1%. 1301-A, $595.

10c-100 kc extremely stable RC oscillator, output voltage constant ±1 db. 1302-A, $500.

20c-40 kc essentially constant output voltage (±0.25 db for 20c-20 kc), very low distortion. Ideal for frequency-response testing of audio equipment. 1304-A, $680.

20c-12 Mc, and 30 Mc to 42 Mc, sine waves; 20c to 2 Mc, square waves. Can be set to any center frequency from 20 kc to 12 Mc or 36 to 42 Mc and driven at any sweep width up to ±6 Mc. Sweep rate is 60 cps. 1300-A, $1950.

5kc-50 Mc 1 watt output at rf; internal 400- and 1000-cps modulation. Excellent shielding for bridge use. 1330-A, $635.

STANDARD-SIGNAL GENERATORS

5 kc-50 Mc up to 2 volts open-circuit output. 20c to 15 kc external, or 400c internal modulation adjustable from 0 to 80%. 1001-A, $975.

16 kc-50 Mc 4 volts open-circuit output. Incremental frequency changes possible to 0.01%. 50c to 15 kc external, or 400c and 1000c internal modulation adjustable from 0 to 100%. 805-C, $1975.

40-250 Mc, 1021-AV, $740;
250-920 Mc, 1021-AU, $725;

1 volt out at 50 ohms. 30c to 15 kc external or 1 kc internal modulation adjustable from 0 to 50%. Both instruments use same cabinet, power supply, and modulation unit, $290. VHF Oscillator Unit $450, UHF Unit $435.

*Unit Power Supply required; $50 extra.

RF, VHF, UHF

0.5-50 Mc, 1211-B, $295*
50-250 Mc, 1215-B, $210*
65-500 Mc, 1208-B, $230*
180-600 Mc, 1209-BL, $260*
250-960 Mc, 1209-B, $260*
450-1050 Mc, 1361-A, $285*
900-2000 Mc, 1218-A, $465*

The best general-purpose oscillator buy available anywhere . . . compact . . . low-cost . . . covers wide frequency range with single-dial control . . . high output . . . good shielding . . . excellent stability . . . useful for all types of laboratory measurements or can be built into special assemblies . . . readily adapts to sweep operation . . . can be modulated by other signal sources.

PULSE GENERATORS

Popular general-purpose Pulser; repetition rates, 30c, 60c, and 100c to 100 kc in X1, X2, and X5 steps or 15c to 100 kc continuous with external drive. Duration, 0.2 μsec to 60,000 μsec. Output: 20v max. open circuit. 1217-A, $250*.

Pulse, Sweep, and Time-Delay Generator . . . a complete pulse system; repetition rates 0 to 250 kc, duration 25 mμsec to 1.1 sec, time delay 1 μsec to 1.1 sec, delay repetition rates 0 to 400 kc, sweep durations from 3 μsec to 120,000 μsec. 1391-B, $2025.

Time-Delay Generator; two independent delay circuits: 0 to 1.1 sec, and 0.5 μsec to 0.5 sec; can be combined for a total delay of 1.6 sec, or used independently as a coincidence circuit for producing pulse bursts. 1392-B, $1095.

SPECIAL-PURPOSE GENERATORS

Random-Noise Generator; 5c to 5Mc broadband noise source with up to 3v output. 1390-B, $295.

Time/Frequency Calibrator; compact secondary frequency standard with fixed outputs at 10 Mc, 1 Mc, 100 kc, and 10 kc; harmonics usable to 1000 Mc. Short-term accuracy after standardization is 2 parts in 10^7. 1213-D, $310*.

Standard-Frequency Oscillator; the "heart" of the G-R Frequency Standard. A 5-Mc crystal oscillator with a short-term stability of better than 1 part in 10^{10} per minute, as measured with 1-second samples. 1113-A, $1550.

Klystron Oscillator; compact microwave source covers range from 2.7 to 7.46 Gc (depending on klystron used). Internal 1-kc square wave modulation; may be pulse or frequency modulated from external source. 1220-A, $235* (less klystron).

Write for Complete Information

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